HUSBAND

ON THE

ÆSTHETIC TREATMENT OF BRIDGE STRUCTURES.

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OF

BRIDGE STRUCTURES.

BY

JOSEPH HUSBAND, Assoc. M. Inst. C.E.

WITH AN ABSTRACT OF THE DISCUSSION UPON THE PAPER.

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"The Æsthetic Treatment of Bridge Structures."

By JOSEPH HUSBAND, Assoc. M. Inst. C.E.

THE subject of the æsthetic treatment of the design of engineering structures in general has perhaps not received that systematic attention from engineers to which it is entitled. Their apathy has been more especially marked until fairly recent times, when a new interest has been aroused in principles, the due observance of which tends to the production of a pleasing effect in structures otherwise prone to assume an exclusively utilitarian character. Some explanation of this may be sought in the limited choice of materials and constructive appliances at the disposal of the early engineers; and such limitation, in conjunction with the greater difficulties involved, might well exert a deterrent effect on any inclination to complicate further the design of structures which, from considerations of utility alone, already constituted a sufficiently difficult task.

In the treatment of such a subject, it is manifestly impossible to attempt to lay down definite laws for guidance in the design of engineering structures; and it is the object of this Paper to notice a few of the more salient features of design in modern bridge construction, which, considered with a due regard to correct proportion and pleasing appearance, go far to enhance the æsthetic effect of the completed work.

In these days of gigantic structures, the importance of rapid execution, the restricted choice of material, the consideration of the best methods to overcome the varied difficulties presented by situation and foundations, and last but not least the necessity for the observance of strict economy, militate strongly against successful æsthetic treatment. Bearing these considerations in mind, criticism on æsthetic grounds can be offered, in the majority of cases, only by ignoring many of those conditions which exert a

decisive influence on design, especially in its initial stages. Not a little of the adverse criticism of engineering structures has been the result of attempts to compare them with wrong ideals. The age of iron and steel construction has created new and distinctive types, such that any attempt to reconcile them with previously existing models, often in totally different materials, cannot but end in failure.

The size of a structure plays a most important part in inspiring the conception formed of it; and again, the same structure will excite varying emotions in persons of different temperament or calling. In fact, the conditions affecting æsthetic considerations are so numerous and complex, that it is small wonder so few structures have succeeded in establishing a claim to anything approaching universal commendation.

Although it is highly inadvisable to attempt to establish a multiplicity of rules for the control of æsthetic principles in design, yet it seems desirable that one or two fundamental ones should be observed whenever possible. One of the most important of these is that the special purpose for which any structure is erected should be regarded as of such paramount importance in its design as to create in the mind a satisfactory impression of the suitability of the particular design adopted for meeting the exigencies of the case. Nowhere is this fundamental rule better exemplified than in Nature. A tree is undoubtedly one of the most beautiful of natural objects; yet even to the least trained mind it is apparent at a glance how stability is assured by the splaying out of the roots around its base, and a perfect balance is obtained by the shooting of the branches in every direction; whilst the decreasing girth of the rising trunk provides exactly the diminishing strength required for resisting the pressure of the wind and for carrying the weight safely. Similarly the outline assumed by a lofty mountain through ages of constant weathering irresistibly suggests the gradually spreading base so necessary to insure stability in massive structures. Many such natural examples will suggest themselves; and nothing is more probable than that the earliest structures erected by man were slowly evolved from a due consideration of natural objects. Where, then, any artificial structure contains such elements as, on contemplation, instinctively suggest natural prototypes, no better could have been followed, in so far as is consistent with the materials at disposal. It should be noticed, however, that this principle, like all others, may suffer abuse by the attempt to copy too slavishly any natural object, and especially any living creature.

Simplicity of design is another eminently desirable quality in a

truly æsthetic structure. Here again Nature points the way; for in every case the most beautiful and perfect result is obtained by the most economical expenditure of material and the simplest arrangement of parts for accomplishing the object. An unnecessarily complicated arrangement of detail, or a recurrence of redundant parts in a structure, only bewilders the mind, instead of pleasing by the rapid appreciation of the fitness of each constituent member for the performance of its special function.

A third desideratum is proper treatment of the various materials employed, on which depends a large portion of success in securing a perfectly harmonious result. Only too frequently are composite parts of structures elaborated, not so much perhaps in unsuitable materials as in forms unsuitable to the special material adopted; whilst in other cases attempts may be made to present in disguise one material for another, or possibly the resulting effect may be marred by the employment of too great a variety of materials. It is in some degree unfortunate that the most suitable material for the construction of bridges of great magnitude should be one which lends itself so little to æsthetic treatment. In this respect iron compares unfavourably with stone, although much of the superiority accorded to the latter is probably due less to any intrinsic value than to a longer familiarity with its appearance and to a more artistic development in its application; in other words, the age of stone has seen its palmiest days, whilst that of iron may well be in the future.

A pleasing effect in any structure may perhaps be said to be largely producible in either one of two ways, or in the temperate combination of both. In the first, a truly æsthetic result may be achieved solely by paying due regard to the purpose for which the structure is required, and so proportioning its parts that the utilitarian and economical elements are blended and simultaneously appreciated by the beholder. In this case any added ornament is not only unnecessary, but entirely foreign to the end in view. To this method of treatment may be relegated most metal bridges of large span, and it is of importance that structures of this class should have most careful thought bestowed upon them, since they form prominent features in the landscape. A second mode of treatment is that in which an otherwise distasteful appearance may be screened by a judicious application of ornament in such a manner as to hide the bare constructive detail, without at the same time effacing the leading features of the general structural design. As illustrations of this kind of treatment may be cited many arched bridges of small or medium span, which, constructed essentially of several metal ribs of economical design,

have the visible portions of the arch and spandrels masked by a more or less ornamental facial rib. Here the arch principle is preserved, whilst the general appearance is enhanced, often with great success. A third method is sometimes applied, frequently with very unsatisfactory results; namely, that in which external ornament is added indiscriminately to every portion of the structure which offers the slightest opportunity for such treatment. In this case the applied ornament may be, and often is, irreproachable in detail; but, being greatly in excess of the real requirements, or perhaps of too florid a nature, it ruins what might have been, under more temperate treatment, a considerable success.

Considering bridge structures from an æsthetic point of view, it seems advisable to arrange them in three distinct classes. First, those erected entirely in masonry or allied materials, and in which metal plays no part; secondly, those constructed exclusively of iron or steel; and thirdly, those in which both stone and metal are employed.

The first class, under the present conditions of design, is generally considered to be much more susceptible of successful æsthetic treatment than either of the others. The principal reason for this may be found in the close alliance of the masonry types to architectural structures in general, providing the designer with an almost unlimited wealth of precedent and experience from which to elaborate the design. In regard to facility of treatment, the purely metal structure stands second; and, generally speaking, such structures will score the highest æsthetic success when treated with a certain amount of severity and boldness, due respect being paid to properly emphasizing the economic principle of the design. The third class, in which iron and masonry are combined, often in fairly equal amount, will perhaps always remain the most difficult for correct æsthetic treatment, since it appears almost impossible to reconcile structural details tastefully in two such dissimilar materials.

It is noteworthy that of these three classes the first comprises, generally speaking, representatives of what may be called small-span structures, the majority of masonry bridges being less than 150 feet in span. The second class includes nearly all the most gigantic bridge structures, whose great height and specialised design have largely prohibited the use of masonry piers. The third class includes the greater number of bridges of intermediate span, which, with the exception of viaducts of great altitude, generally consist of metal girders carried on masonry piers.

As this appears to form a convenient classification under which to regard the subject in its æsthetic aspect, it is proposed to

consider the various types of bridges in the above-mentioned order.

Masonry Bridges.

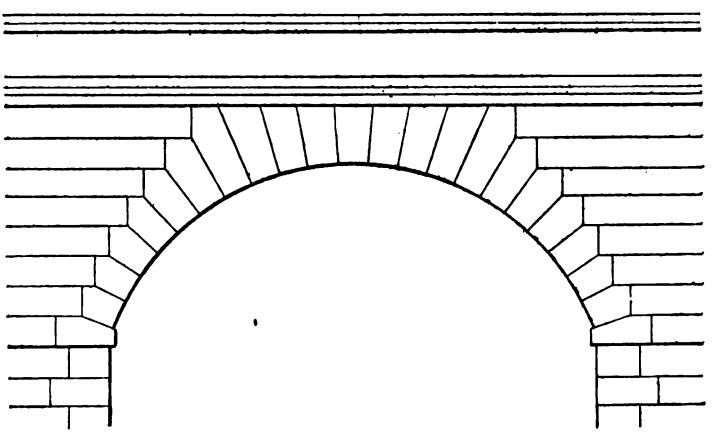
The essential feature of bridges constructed entirely of masonry is the arch, and the arched bridges of the present day are the result of a process of differentiation from the small-span arch of earliest architectural times. Three distinct varieties are easily identified—the semicircular, the segmental and the elliptical. The semicircular arch is better adapted to the requirements of architecture than to those of engineering, and, in the latter case, it appears to best advantage when carried on a succession of lofty piers. The segmental and elliptical arches attain their highest æsthetic value when employed in comparatively low-level or single-span bridges, usually of larger opening than the semicircular arch. Of the two, the segmental arch, when carefully treated, generally produces a greater impression of strength, and conveys a subtle suggestion of the thrust being more directly transmitted to the abutments. This is not so in the case of the elliptical arch, the greater flatness at the crown of the latter tending to create a feeling of insecurity, together with apprehension in respect of the more strongly rounded haunches.

It may not be out of place here to refer briefly to the use of approximate elliptical curves formed by joining a number of arcs of circles. Wherever the elliptical form of arch is adopted, it is certainly desirable to employ the true ellipse for its outline, since no approximation to any real curve can rival it in æsthetic effect. When, however, for the sake of simplicity or convenience it is decided to retain the less accurate design, the employment of at least nine centres to thirteen centres should be regarded as essential to the scheme of approximation.

A point of vital importance in the masonry arch is the treatment of the visible faces of the voussoirs. In *Fig. 1* is represented a style of arch occasionally employed, in which the depth of the voussoirs diminishes from the crown to the haunches. The predominant impression created is one of top-heaviness and neglect of the primary structural demands of the arch. It is not suggested that this form may never lay claim to effective or beautiful appearance, but it should be used with caution and perhaps be restricted to the semicircular arch. Wherever its employment is attended by success, this is due chiefly to its obvious agreement with neighbouring details of the masonry, rather than any intrinsic merit. As regards the depth of voussoirs, the principal

step towards success in a design is not only to adhere truthfully to the essential requirements of the thrust in the hidden portion of the structure, but also to give due value and emphasis to this principle on the exposed face of the work. The most æsthetically successful large-span arches are those in which the depth of the voussoirs is suitably increased towards the haunches, and in which the shape of each voussoir is distinctly apparent. The thickening of the masonry rib at those points where theory demands it, evokes, even in the untrained mind, a feeling of security, whilst the individuality of the ring-stones aids in enforcing the magnitude of the design. At this

Fig. 1.



juncture two distinct styles of treatment appear. In several cases the arched ring has been carved into a heavy moulding and the individuality of the voussoirs has been entirely suppressed. This is the method of treatment followed in the Grosvenor Bridge over the River Dee.[1] In Figs. 2 and 3, Plate 2, are shown respectively outlines of this notable structure, and of a similarly proportioned arch in which the opposite treatment is adopted; incidentally the spandrel details are differently shown, in illustration of a subsequent matter. For reasons which will presently be mentioned, the latter is probably the more pleasing of the two designs. The moulded arch in early architecture was almost exclusively adopted for small spans of semicircular outline; and by frequent repetition through many centuries it has in

[1] Transactions Inst. C.E., vol. i. p. 207.

a great measure come to be regarded as the most suitable and legitimate design for this particular form. Consequently its attempted adaptation to the case of a large-span arch of totally different outline must naturally produce in the mind a dwarfing impression. The number of voussoirs in an arch goes far to accentuate a conception of largeness; up to a certain point, increasing the number of voussoirs produces a corresponding suggestion of increased size in the whole arch; but if they are too numerous, there is risk of the structure losing its megalithic character.

The proportion of rise to span, so important a matter in the construction of an arch, is of scarcely less influence on the final appearance, pleasing or otherwise. Very few masonry arches of large span can be said to err in this respect, since, in order not to overstep the limits of boldness, a liberal amount of rise is usually allowed; and the rise, being so apparently a necessary factor in the constructive design, is equally important in its effect on the general appearance, avoiding, as it does, any suggestion of weakness or excessive thrust.

Before leaving the consideration of the outline of the arch, mention should be made of the special form given to it in such examples as the Gloucester Bridge over the Severn, the Pont du Neuilly over the Seine, and the Dora Riparia near Turin.[1] In these instances the soffit of the arch possesses two distinct outlines—a very flat segment on the face, and an ellipse or rounder segment for the soffit proper, a heavy inward splay occurring at the haunches, which gradually dies away towards the crown, where the two curves coalesce. This design, originally due to Perronet, in addition to affording a pleasing effect of lightness and grace, also leads to economy in material.

Turning to the consideration of the spandrel-walls, an inspection of most existing examples would seem to indicate that this portion of the structure offers limited scope for variety of treatment. So far as the arch as an engineering structure is concerned, three prominent styles of treatment appear to have been followed. Figs. 2, 3 and 4, Plate 2, show at a glance the predominant features of each. In Fig. 2 is outlined the general effect produced by strongly throwing up the arch-ring by a heavy moulding, and inserting in the spandrels a triangular panel with moulding more or less in keeping with that of the voussoirs and cornice. It is easy to imagine that, having decided on the adoption of a moulding for the ring, a similar method of treat-

[1] Transactions Inst. C.E., vol. i. p. 183.

ment should suggest itself for the spandrels. This design is open to the objection already mentioned; moulding being so generally applied in architecture as an ornamental detail on a comparatively small scale, the general effect is not conducive to a correct appreciation of the leading dimensions of the structure. Possibly improvement might be effected by breaking up the large panels into three or four of smaller size, and thereby introducing more detail into the design. Fig. 3 shows the general appearance of those arches in which the megalithic character of the work has been preserved, both in the voussoirs and in the spandrels. Here again the suggestion of progressive similarity of treatment is traceable, stones of similar dimensions being utilized in both portions of the arch; and the joints being emphasized by deeply-chiselled drafts below the general surface, an eminently pleasing effect is obtained. The large number of bridges erected after this style of treatment affords sufficient evidence of its success. If at all open to criticism, it may perhaps be charged with lack of detail and excess of uniformity, but it is chiefly these attributes which render it of special value in large-span arches. In Fig. 4 are indicated two methods of lightening the spandrels by piercing them with openings of a design in keeping with the other details. The adoption of either method necessitates a modified construction in the bridge, and is best applied where the breadth of the structure is not excessive; otherwise a slightly oblique view will rob the design of its essential feature, by blocking the openings in the spandrels. Besides the effect of lightness thus obtained, the additional detail here distinctly accentuates the value of the dimensions of the structure; and it is to be regretted that so many arches with hollow spandrels should not, by a slight modification in construction, have been treated in this manner. A partial effect of this nature may be obtained by dividing the spandrels into a series of arches thrown up in fairly high relief against the general surface of the head-walls, and separated from one another by pilasters. A fourth variety of treatment would be to enrich the spandrels with sculpture, but as this belongs more exclusively to highly ornate architecture, it scarcely comes within the scope of the present Paper.

It is open to question how far the employment of exactly similar arches in high viaducts consisting of several spans is compatible with true artistic effect. For an arch of given height there will be one particular span which will produce a more pleasing effect than any other; and if this proportion be satisfactorily fixed for the highest arches of a series, it is strictly in

keeping with æsthetic principles to retain the same proportion for the remaining spans, thus decreasing the spans as the height becomes diminished. In illustration of this, reference may be made to *Fig. 5*, which shows in outline the Bridge of Trajan at Alcantara. This ancient example plainly indicates that the Romans were fully alive to the due observance of æsthetic laws in their engineering structures. Perhaps the least pleasing feature in the design is that the arches spring from different levels, although the structural objection to this is partially balanced by the reduced thrust in the smaller arches. This design is of course at a considerable disadvantage, regarded from an economical standpoint, more piers and a great variety of centering being required in construction; probably for these reasons it has not found favour in modern times. The same principle has often been successfully applied in bridges which have a gradual rise from abutments to centre, such instances, however, being quite distinct from the example illustrated, where the roadway is horizontal.

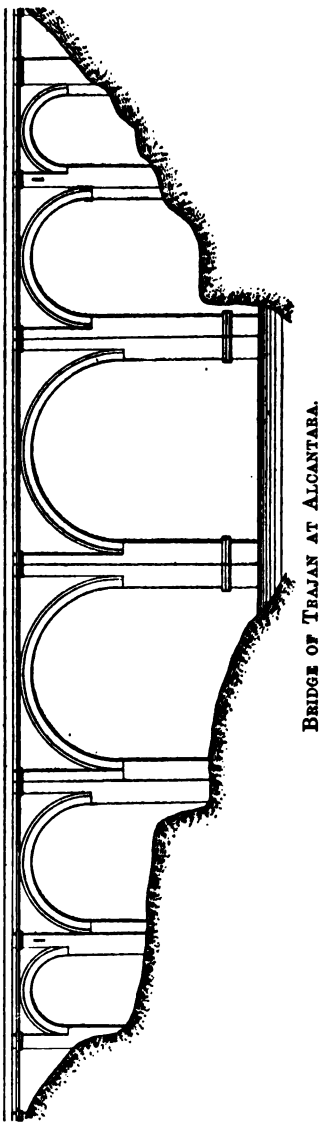
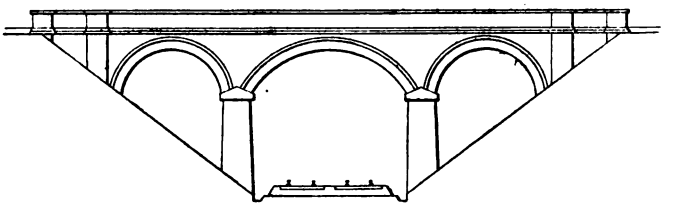


Fig. 5. Bridge of Trajan at Alcantara.

A case which frequently arises in connection with railway engineering is the employment of a three-arched bridge for carrying a road over a wide cutting. Here the proportions of the central arch are regulated by its height and the dimensions of the permanent way, and those of the side arches by the slope of the cutting. Wherever possible it will of course be advisable to make all three arches of the same span; in many cases, however,

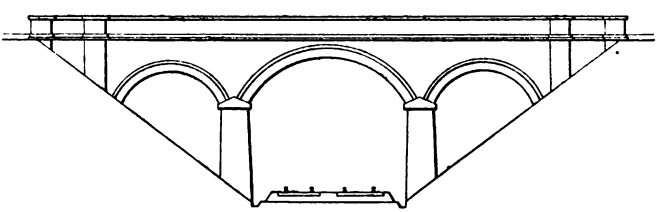
this cannot be conveniently arranged, and the two side spans are frequently less than the central one. The question then arises whether it is better to bring up all three to the same level at the crown by adopting different proportions for the outer spans, or to employ three arches of similar outline. An inspection of *Figs. 6* and *7* will show the latter to be preferable, although the

Fig. 6.



former is not infrequently met with. Where the relative levels of road and railway admit, the appearance of the latter may be still further improved by giving a suitable amount of camber to the parapet.

Fig. 7.



Piers.—Turning to the consideration of the piers of masonry bridges, it seems advisable to regard them as belonging to one or other of two main classes, since fairly distinct differences are presented in the design of high-level and of low-level piers. A salient feature in the lower portion of nearly every river pier is the cut-water or buttress which is almost always provided, sometimes where not absolutely required; this feature, having often bestowed upon it a considerable amount of ornamentation, naturally becomes more prominent in low-level than in high-level piers, being terminated at or about the flood water-level in the latter, whilst in the former it is frequently carried in a modified form up to or above the parapet. Principally for this reason the lofty pier presents fewer opportunities for variety of treatment

than does the low one. The former on account of its height and weight demands a suitable increase in its basal dimensions, both for structural reasons and in order to inspire a feeling of confidence in its stability. This increase may be accomplished in several ways; Figs. 8, 9 and 10, Plate 2, show three of the most common of them, whilst many combinations of these may be employed. When properly carried out, all three achieve the desired object of suitably reducing the intensity of pressure on the foundation; but the curved outline of Fig. 9 is undeniably the most pleasing in appearance, besides creating most powerfully an impression of stability. No more satisfactory examples of this type can be cited than the piers in the approach viaducts to the Forth Bridge. The forms shown in Figs. 8 and 10 both have a more severe appearance, and of the two the latter is perhaps the more effective when used in combination with segmental arches. Above the springing the head-walls may be left quite plain—the better mode where environment specially calls for strength or rusticity—or the piers may be continued upwards in effect by the addition of a breast of masonry extending to the parapet, in situations where a little more ornament will harmonise with the surroundings. The pleasing application of the latter mode of treatment is illustrated in Figs. 11 and 12, outline elevations respectively of Cartland Crags Bridge, near Lanark, and the Dean Bridge at Edinburgh, both by Telford. In high railway viaducts this detail lends itself to a suitable termination in empanelled refuges thrown out in relief against the parapet-wall. Incidentally, the employment of an outer rib beneath the footpath, as in the Dean Bridge, Edinburgh, suggests a construction which might be applied with good effect in bridges undergoing widening. A practice which is as little conducive to beauty as it is necessary in construction is that of forming deep grooves down the faces of masonry piers for the insertion of iron pipes for the drainage of the spandrels; that this continues to be perpetrated when it might be so easily avoided, can be due only to utter indifference to æsthetic considerations.

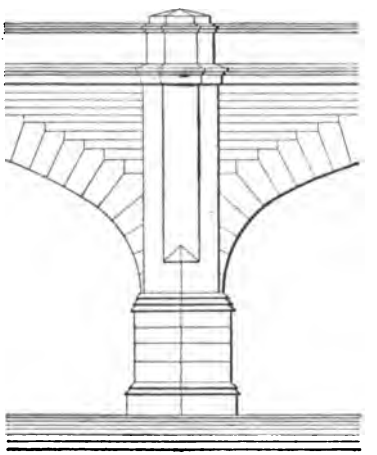
In some recent viaducts something in the nature of a revival of the employment of abutment-piers has occurred. Without expressing any opinion as to the structural value of these piers, it must be admitted that they have an unpleasing effect on the general appearance of the work. This effect is even more marked in a short viaduct of nine or ten arches, where only one abutment-pier is erected, than in a much longer structure, in which, every fifth or sixth pier being enlarged, the regularity caused by

repetition is less suggestive of incongruity. Bearing in mind the special function of such piers, it requires an effort to reconcile their presence with the purpose of the bridge, since, so long as the structure remains intact, they have no apparent function to perform. Could such a viaduct be viewed in a partially collapsed condition, such that the abutment piers were called successfully into action, an instant appreciation of their desirability would be formed.

Reverting to the consideration of the piers of low-level bridges, the salient feature from the water-level to the springing is the cut-water. This, from the nature of the requirements, offers somewhat limited scope for treatment, and is almost invariably constructed V-shaped in plan, the sides of the V being sometimes rounded, whilst occasionally the cut-water is semicircular. The V shape is the more correct, by reason of its greater capacity for stemming the current. Although for utilitarian purposes a cut-water is only required on the up-stream side of a pier in non-tidal waters, yet the symmetrical and stable appearance of the pier is greatly enhanced by the general practice of constructing one on the down-stream side also. Although the provision of a strongly defined cut-water on the up-stream side only is strictly in keeping with the constructive requirements of the case, yet the superior appearance of two cut-waters in this instance seems to constitute, to some extent, an exception to the primary laws of æsthetics: possibly the idea of the mobility of water exerts an unconscious influence on the judgment. The principal opportunity for variety in design occurs at the springing, where the cut-water has to be either suitably terminated or somewhat modified prior to being continued up the face of the masonry, whilst at the same time the arch-ring has to be so united with the body of the pier as not to vitiate a true appreciation of the transfer of thrust from the adjacent arches to the pier. The existing examples of bridges in which the cut-water terminates at or near the springing-level are generally so unsatisfactory that it is not surprising the majority of really successful structures should have been treated in the opposite manner. With elliptical or semicircular arches it is obligatory, without unduly increasing the width of the pier, to hide the greater portion of the last few voussoirs behind any superstructure erected upon the cut-water, and in such cases the most pleasing effect will be attained by giving the mouldings or other ornament of the superstructure a strongly vertical character, in harmony with the well-defined resultant pressure due to the adjacent spans. On the other hand,

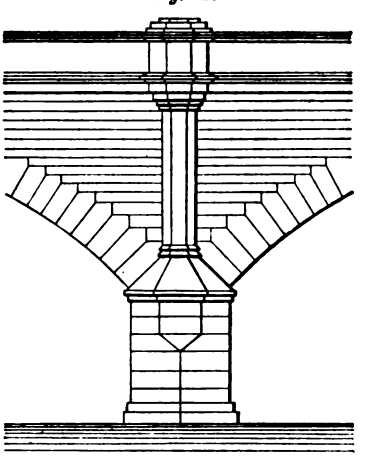
in fairly flat segmental arches, it is questionable if a better result be not secured by allowing the voussoirs at the springing to remain wholly visible, which may easily be accomplished by carrying up the superstructure in the character of a pointed or octagonal pilaster of considerably reduced width. *Figs. 13* and *14* indicate in as few lines as possible the general effect of these two modes of treatment.

Fig. 13.



A few words may be said here regarding the use of classical pillars or pediments on this portion of the structure. The pillar is essentially a weight-bearing member, and in order to show to the best advantage, this feature should be duly emphasized. Its employment, generally in the form of a fairly massively proportioned member, for the superstructure upon the cut-water of a bridge is seldom successful, since at the most its supporting function is limited to merely carrying the weight of a short entablature surmounted by the parapet. Added to this, the use of the pillar in classical architecture is so generally associated with repetition—pillars being usually grouped to form colonnades in which four is the minimum number employed — that the sight of a pair of columns or a single detached pillar upon the face of a pier gives rise to a suggestion of strangeness and isolation. For these reasons London Bridge may perhaps be regarded as of higher æsthetic value than Waterloo Bridge.

Fig. 14.



Were it advisable to employ a columnar design for the cut-water itself, the result would be much more satisfactory, since the pillars

might then be suitably grouped, and have superimposed upon them a considerable mass of masonry, thus calling into play the significance of their essential function. In the same way, the pediment being so intimately associated with temple architecture, its adoption is often a greater solecism than that of the pillar. Another architectural feature which is frequently abused in its application to bridge construction is the semicircular niche. This is so customarily adopted in architecture as a canopy for life-sized statuary, that its irresponsible employment in masonry bridges of considerable size gives rise to a dwarfing effect similar to that caused by the misapplication of moulding and panels. The effect will be appreciated by a further reference to the example shown in Fig. 2, Plate 2.

Attention is now directed to the treatment of the cornice and parapet. The latter detail is so obviously necessary that its employment will certainly not be called in question; and the only debatable point is whether it is better to adopt an open-work parapet with balusters or tracery, or a perfectly plain one, perhaps relieved with panels. In both cases its continuity may be interrupted by carrying up the superstructures of the cut-waters in some suitable manner to form supports for lamp standards, ornamental finials, or canopies for statuary. It may also be desirable to introduce other breaks in the parapet, midway between the piers, and to combine these with a panel or ornamental pilaster springing from a prominent key-stone. Such panels or pilasters will plainly be so subservient to any erections which may be continued above the piers, that they will require correspondingly subdued treatment. Fig. 15 suggests in a rudimentary manner two or three variations in the application of this treatment. It may be remarked that erections of the nature just described will be most effective on a bridge with a perfectly horizontal parapet: where the parapet is strongly cambered from the approaches to the centre of the bridge, any such constructions would generally necessitate horizontal bases projecting a little way above the parapet, and making with it different and somewhat awkward angles. Whether the parapet of a long bridge should exhibit a horizontal or a cambered outline depends largely on relative levels and on considerations of headroom near the centre of the structure. The two outlines are equally graceful when due care is exercised in adapting the design to the requirements of the environment. The cambered form appears to better advantage in a low-level bridge than at a greater altitude, whilst the opposite is generally true of the horizontal type. A long, low-lying

bridge with a perfectly level parapet is apt to appear slightly depressed, when viewed from certain situations—a defect easily rectified by giving to roadway and parapet a very slight upward curvature. On the other hand, in gazing upwards at the broadside presentation of a high-level bridge the perspective effect applies a sufficient correction to this tendency.

In work of a less ambitious character it frequently happens that it is necessary to construct the bridge with an inclined roadway. In this case a method of treatment is not uncommonly practised, in which the bed-joints of the masonry adhere to the horizontal in the spandrels and facework generally, whilst in the parapet they follow the direction of the incline, producing anything but a pleasing appearance. In some instances, perhaps, this cannot be easily rectified; but a suitable way of meeting the difficulty where the inclination of the parapet is strongly marked would be to employ a neat stepped parapet, in which the courses might retain their horizontality.

The elevational view of a masonry bridge with a strongly marked cornice below the parapet irresistibly suggests the level of the roadway behind, and consequently fixes a limit to the presumed thickness of the arch. Where sufficient headroom is available, the arch-ring may be situated at such a depth below the parapet that an appropriate cornice may be introduced without interfering with the continuity of the voussoirs near the crown, and in such cases the presence of a cornice is desirable. Where, however, the headroom is so limited that this interference can neither be avoided nor be so satisfactorily dealt with as not to create an impression of insufficient thickness at the crown, it is optional to omit the cornice and to carry the head-wall up to the parapet-coping. If this be done, the fundamental idea of the parapet is annihilated, together with the appreciation of the relative levels of keystone and roadway, and an apparent accession of strength is given to the arch. *Figs. 16* and *17* respectively, illustrate these two instances. The latter can be carried out only at a considerable sacrifice of ornamental detail; yet the design has the merit of appearing better able to perform the duty required of it, and there is also less temptation to insert some kind of possibly unsuitable panel-ornament in the spandrels.

Abutments.—Before leaving the subject of masonry bridges it is necessary to notice briefly some of the leading features in the design of abutments. The piers and abutments of any bridge should exhibit some degree of uniformity in design. For instance, if it be decided to employ a certain outline of buttress for the

faces of the piers, it will probably be safer to repeat something of similar outline on the wing-walls of the abutment, rather than risk the effect of some untried design of a totally different character. Again, where the piers are continued above the level of the parapet, some similar projection will be requisite at the approaches to the bridge. It is extremely difficult, however, to

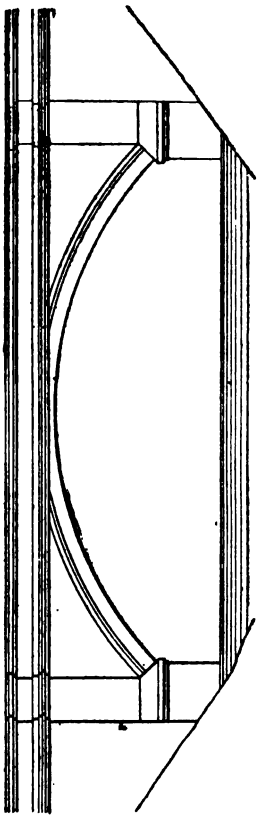


Fig. 16.

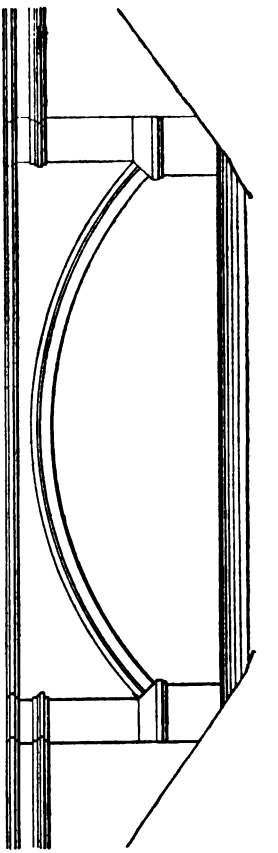
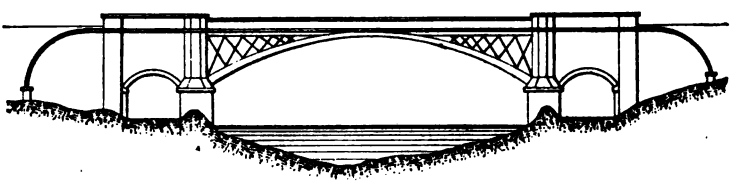


Fig. 17.

point to anything in the nature of hard-and-fast rules in the consideration of this detail, which presents so many opportunities for variation in design. An important point is, that the abutments should be of sufficiently massive proportions to convey an impression of their ability to resist easily the very obvious oblique thrust occurring at the shore ends of the bridge—their treatment in this

respect demanding something in contradistinction to the strong vertical character of the piers, so markedly implying resistance to a vertical resultant. This demand may in general be satisfied by emphasizing the skew-back at the abutment, by allowing the joint between the last voussoir and the springing-course to be wholly visible, and by slightly setting back the main bulk of the masonry of the abutment. Many segmental arches suffer in effect from an insufficient display of material in the skew-backs. In many single-arch bridges of large span, the exigencies of the site have necessitated the construction of a couple of much smaller arches, either through the abutments or immediately in their rear. That the appearance of the main arch must suffer to a certain extent by this treatment seems highly probable for several reasons: the land arches are inevitably of different outline from that of the central span, their crowns cannot be raised to the same level without producing a certain degree of attenuation, whilst their detail is very apt to suffer by comparison with the central arch.

Fig. 18.



A somewhat flagrant example of this is illustrated in Fig. 2, Plate 2, where the land arches not only fail to harmonise with the neighbouring niches in the abutments, but their detail is quite out of keeping with that of the principal span; they appear, in fact, as if transported from some other structure and accidentally introduced into their present position. A more pleasing example is presented in *Fig. 18*, where, although the principal opening is bridged by a metal arch with a span of 150 feet, the general conditions are similar. Had the roadway on each side of the river been raised, or even had the height of the land arches been increased, the appearance would have been still further improved.

Before passing on to a consideration of the second class of bridge structures, it may be remarked that no amount of care and thought bestowed separately on each detail of a design will produce a satisfactory result, unless at the same time due attention is given to the careful blending of all the details.

Metal Bridges.

In treating of the æsthetic design of the second great class of bridge structures, in which iron or steel is employed both for piers and superstructure, it is manifest that a widely different standard of judgment is called for. As already mentioned, this class includes the majority of very large bridges. In these structures, not only would the addition of ornament be false in principle, as being foreign to the purposes of design, but its systematic application could be indulged in only at the expense of a great increase in weight, with a corresponding sacrifice of economy. From these considerations it is plain that the standard of æsthetic criticism to be adopted depends, firstly, upon the most perfect economic application of material, and secondly, in cases where distinctly optional design is possible, upon the adoption of the most pleasing outline consistent with economy. It has repeatedly been urged that these structures as a class are amongst the least æsthetic ever designed by man. Although this scathing judgment may be true of a few isolated examples in which, apparently through sheer ignorance, the essential principles of æsthetic construction have been totally neglected, yet such a sweeping statement can be the result only of an appeal to standards as false as the verdict is unfair. Unfortunately the obstacles to be overcome in the manipulation and erection of such huge masses of material, generally in situations of extreme difficulty, often preclude the adoption of the most pleasing outline of design; and consequently, whilst few structures fail to comply with the first requirement, there exist several which, but for this consideration, might equally have satisfied the second condition.

This division of the subject may be most conveniently dealt with by considering each representative class separately; and it is proposed to commence with the cantilever type of bridge, and to proceed as far as may be in the order of span for which the several kinds of structure are suitable. The cantilever bridge, more than any other type, has been the object of adverse criticism. Why this should be so is indeed difficult to explain, unless it be that, constituting as it does the latest evolution in structures of very large span, the popular mind has not yet become sufficiently familiarised with its principle. Moreover, the special difficulties referred to as incidental to all large-span works naturally affect this class very seriously.

In Figs. 19, 20, 21, Plate 2, are given three representative outlines of the cantilever bridge. The first possesses a horizontal

lower boom, the second a horizontal upper boom, whilst the Forth Bridge has both these members inclined. All three may be said to comply with the main requirement for æsthetic effect, since the depth of the cantilevers in each diminishes outwards from the piers, as suggested by considerations of economy, whilst each is adapted to support a central span. The difference in effect of the outlines, however, is very marked. The first two, and especially the second, can lay very little claim to anything approaching a pleasing appearance, whilst the third is infinitely more graceful than either of the others. Yet it must be remembered that these are merely elevations of the respective structures, and that no elevation of the Forth Bridge can adequately convey an impression of its true æsthetic appearance—rather does it tend to malign it, since it presents the piers as somewhat hard rectangular outlines. When the actual structure is viewed, the perspective effect due to the great height of the piers corrects this slight æsthetic defect, whilst the strong vertical batter in the transverse direction completely removes any lingering suggestion of the rectangular form. Another pleasing feature in this example is the decided curvature of the lower member, producing a beautiful arched outline above the water, without in any way disguising the principles of construction in the design. It has been suggested that the appearance of the Forth Bridge would have been enhanced by the addition of a suitably designed finial at each corner of the towers and upon the extremities of the supported spans. It is difficult to say what would constitute a suitable finial here, and in all probability the effect of such an addition would be ridiculous, since a structure like this derives its beauty chiefly from its inherent strength and unparalleled dimensions, and any attempt at outside ornament must be detrimental in effect. Such a method of procedure as that suggested was followed in the swing span of the Harlem Ship Canal Bridge at New York;[1] and although this is a structure of much smaller size (though not dissimilar in shape), the result cannot be said to be unexceptionable.

It has also been suggested that the cantilever is more successful æsthetically when employed with a single instead of a double arm. This instantly sacrifices the pleasing air of balance possessed by the latter type, besides unnecessarily complicating the difficulty of erection.

Fig. 22 is an outline of the Sukkur Bridge over the River Indus.[2] It is an example in which the single-armed cantilever is

[1] Minutes of Proceedings Inst. C.E., vol. cxxx. p. 220.

[2] *Ibid*, vol. ciii. p. 123.

employed with land ties in the rear for maintaining the balance. In this instance the design was particularly affected by the special difficulties attending both the site and the erection; and neglect of the due consideration of these points has frequently led to somewhat unmerciful criticism of the appearance of the bridge. After making due allowance for them, however, it must be admitted that, as a representative of the single-armed type, it cannot compete successfully with the previous example.

In Figs. 23 and 24 are shown two modes of treatment of the cantilever bridge, in which an attempt is made to disguise the break in continuity occurring at the junction of the cantilevers with the central girder, in order to present in the one instance the suggestion of an arch, and in the other that of a suspension bridge. Both methods are impostures, and the diminishing depth towards the centre of the suspended span violates the primary law of economic design.

One other example may be referred to before leaving this class of structure. Figs. 25 and 26 illustrate the outlines, respectively, of the Jubilee Bridge over the Hooghly,[1] and of the Borcea Viaduct over an arm of the Danube. These two structures are identical in principle and not dissimilar in dimensions. In the latter the material is distributed according to the demands of economy, whilst in the former the cantilever span is fundamentally faulty in design. In fact, the central and side spans of the Jubilee Bridge as erected belong to such widely different classes of girders that their similar shape produces conflicting ideas in the mind of the least professional observer. Although the Roumanian example may not be perfect, yet a comparison of the two on æsthetic grounds is strongly in its favour.

The simplest form of suspension bridge will probably always enjoy a considerable advantage over other types, because it is the only structure in which Nature is allowed an almost entirely free hand in adjusting the outline. The chain suspended across the span assumes naturally the most appropriate curve for the performance of its duty; and the subsequent addition of the weight of the platform effects but a trifling modification in its form. Those bridges in which no attempt is made to control the flexibility of the chain almost invariably achieve the highest æsthetic success, although at a sacrifice of practical utility; and again, those in which the approach spans are supported by the land chains, imparting to the latter a curve similar to that of the chains in

[1] Minutes of Proceedings Inst. C.E., vol. xcii. p. 73, and vol. cxxiii. p. 406.

the central span, are more graceful than those with practically straight anchor-chains. The pronounced camber generally given to the platform also exerts considerable influence upon the appearance, although it is quite possible in exceptionally light bridges to exaggerate this feature to the faint suggestion of a very flat arch. It will be generally admitted that the usual design with two supporting-towers is æsthetically superior to the mode of construction with a single central tower, possibly on account of the larger number of natural precedents of the former kind with which the mind is familiar.

Turning to a brief consideration of the various forms of the rigid suspension bridge, the commonest of these are indicated in Figs. 27, 28, 29 and 30. In Fig. 27 is shown the elevation of this kind of bridge with a horizontal stiffening-girder, sometimes reinforced by several sloping ties from the summits of the towers. This form, from its close resemblance to the flexible design, will probably be accorded second place as regards artistic merit, although the appearance is attained at a somewhat considerable sacrifice of economy. The Brooklyn Bridge may be taken as typical of this class, and few will dispute the satisfactory character of its appearance. Of the remainder, Figs. 28 and 29 illustrate optional methods of stiffening the chain, and Fig. 30 that in which both chain and platform are stiffened by the insertion of diagonal members in each panel. Much controversy has arisen as to the advisability or otherwise of employing braced chains, so far as æsthetic considerations are concerned. The majority of examples in which this form of construction has been adopted certainly do not present an entirely pleasing effect. Of the two variations in design illustrated in Figs. 28 and 29, the chain with bracing of uniform depth, besides being objectionable for certain structural reasons, possesses the less graceful appearance, exerting a somewhat oppressive influence on the lighter portions of the structure. The fourth method of obtaining rigidity, shown in Fig. 30, is preferably adopted for bridges in which the rolling load bears such a relation to the weight of the structure as not to render the suspenders liable to compression; otherwise their increased cross section for counteracting this stress will largely neutralize the impression of lightness so essential to graceful effect in this class of structure. The strong resemblance of this design in outward appearance to some forms of the cantilever has already been remarked; and consequently, when carried by metal piers, it may, on a cursory inspection, be confounded with the cantilever, especially if some of the suspenders be designed to resist a thrust. This impression is of course dispelled on a closer examination, or where the

anchorages of the chains are so plainly un-masked as to be easily apparent from a distance; yet the general effect tends to a less prompt appreciation of the suspension principle in this than in other forms.

Although this section of the Paper treats of structures built entirely of metal, yet it may be remarked that the kind of pier adopted for a suspension bridge is a matter of primary influence as regards æsthetic appearance, and those bridges which are supported by masonry piers are in general far superior to those carried on piers of iron or steel. The adoption of metal piers cannot be said to have achieved any decided success. In many examples the design consists of an iron or steel tower, presenting some resemblance to a masonry structure. This is undoubtedly one of the most fatal errors into which the designer can fall. Attempts to imitate, in a plated and riveted structure, the outward form of a masonry arch, as in the piers of the Tay Bridge,[1] or to copy in iron that which in stone is eminently suitable for the propylon of an Egyptian temple, as has been done in more than one notable instance for the towers of suspension bridges, can result only in dire failure. It is possible, in viewing such structures from a considerable distance, to coerce the mind into fancying that they are actually of stone, as their form would suggest; but closer acquaintance robs them of all semblance of propriety. It is much preferable in lofty piers of iron or steel to adhere to some suitably braced design, removed as far as possible from the suggestion of a masonry prototype. When this requirement is duly observed, there is no reason why the metal pier should not be rendered as acceptable on æsthetic grounds as its older relative in stone.

Turning to the portion of the subject exemplified by the arched bridge, the engineer is confronted by an immense array of possibilities in the way of construction. The metal arch is especially liable to criticism, largely perhaps on account of its forcible suggestion of masonry comparisons. That this is a false and unfair line to take has been repeatedly stated; but unless the design strikes out an entirely different course from that pursued in masonry structures, such invidious comparisons will continue to be made. Fortunately something of this distinction has actually been realised in the design of most large-span metal arches, although some examples exhibit strongly many characteristics of the masonry arch.

That the metal arch is capable of eminently successful æsthetic

[1] Minutes of Proceedings Inst. C.E., vol. xciv. pp. 87 and 99.

treatment, provided this idea be carefully followed out, is amply verified by reference to the majority of existing representatives of the type. It should be noted, however, that environment, and especially the relative levels of roadway and springing, greatly affect the general appearance of such bridges. For instance, a large-span arch will appear to better advantage when thrown over a river with high or precipitous banks, and carrying the roadway above or only slightly below the crown, than when it rises to a considerable height above its immediate surroundings, and carries the platform suspended at or near the level of the springing. Between these two extremes any number of variations in design are possible; their necessity depends principally upon the relation of span to height of roadway, whilst some of them are much more susceptible of graceful treatment than others. Their several features are so distinctly marked that they will be treated separately, by considering first the arched rib, secondly the pillars or suspenders according as the platform passes above or below the arch, and lastly the platform itself.

One or other of three distinct modes of treatment is followed in the design of the main ribs of modern large-span arches. The rib may consist of a continuous member rigidly abutting against the piers or supports; or it may be constructed in halves, each springing from a pin-joint at the abutments and meeting on a third pin-joint at the crown; or again, an uninterrupted rib may be employed, resting against pin-bearings at the abutments only. The relative values of these three forms, from a constructive point of view, are too well known to require mention here.

The best-known exponent of the first mode of treatment is the Müngsten Viaduct, whose outline is given in Fig. 34, Plate 3. The finest example of the second class is the Pont Alexandre III. over the Seine,[1] Fig. 31. Familiar examples of the last are that over the Rhine at Bonn,[2] the Niagara Falls and Clifton Bridge, the Grünenthal Bridge over the Baltic Canal, the Garabit Viaduct[3] over the Truyere in France, and the first of the two arches erected over the Douro:[4] the first four of these five bridges are shown in elevation in Figs. 36, 32, 33 and 35. It will be seen that considerable difference exists between the various depths given to the rib in these examples. The prevalent practice in

[1] Minutes of Proceedings Inst. C.E., vol. cxxx p. 335, and vol. cxxxi. p. 402.
[2] *Ibid*, vol. cxxxvii. pp. 466 and 467.
[3] *Ibid*, vol. lxiv. p. 359, and vol. xcv. p. 434.
[4] *Ibid*, vol. lxiii. p. 177.

rigidly abutting structures is to increase the depth of the rib towards the abutments in a manner similar to that followed in large masonry arches; whilst in the pin-jointed arches the rib is either maintained of uniform or nearly uniform depth, or else strongly tapered towards the bearing-points. This latter feature is plainly necessary in effect, whether it be allowed to appear so or not.

Those ribs in which the depth increases towards the springing irresistibly suggest a comparison with the masonry arch, and suffer accordingly; the less the rise, the greater the resemblance and the less pleasing the comparison, since the metal arch of greater rise usually inclines strongly to the parabolic form—an outline rarely adopted in masonry structures. This resemblance to the proportions of the masonry rib is strongly marked in Fig. 36, but much less so in Fig. 34. Whether the roadway be carried above the crown of the arch, or not, probably exerts even a stronger influence in calling up a suggestion of the masonry structure. This is palpably the case in the St. Louis Bridge over the Mississippi,[1] and also in the Washington Bridge over the Harlem River at New York. In both these examples not only is the ratio of rise to span such as is frequently observed in masonry structures, but the spandrels are crowded with vertical supports to an extent which further emphasizes the resemblance; whilst in the latter instance the designer has even gone so far as to employ web stiffeners on the faces of the ribs, arranged in radial lines and at intervals which strongly suggest a resemblance to voussoirs. At the same time the pin-joints at the springing are partially masked to complete the deception still further. This example illustrates in a striking manner the æsthetic unsuitability of allowing one material to masquerade as another of totally different character.

On the other hand, those ribs which possess a strongly tapered outline from crown to springing suggest anything but a masonry type, whilst they exhibit an innate gracefulness peculiarly their own. Perhaps a lingering remembrance of the masonry arch may suggest an insufficiency of material near the pointed ends, but this feeling is instantly dispelled on recollecting the kind of material utilized. It may be this slight appearance of weakness at the springing-points which has led some designers to retain the full depth of the rib throughout its length, and to mask partially or wholly the bearings on the pins. Whilst the situation of the

[1] Minutes of Proceedings Inst. C.E., vol. lxiii. p. 175.

roadway immediately above the crown tends to recall the masonry arch, its location at springing-level equally suggests the bow-string; and where this is liable to happen care should be taken so to emphasize the abutting principle that any idea of structural connection between the curved and the horizontal members may be dispelled. This possibility is well provided against in Fig. 36. The most truly æsthetic effect is perhaps insured by the adoption of the form of arch illustrated in Fig. 33, the Grünenthal Bridge over the North Sea and Baltic Canal. Here the roadway intersects the curve at a height about midway between crown and springing, and the resultant impression is one of grace and lightness quite unrealised by the examples previously considered. The effect is heightened if, as in this instance, a pair of masonry towers of pleasing design from the abutments, controlling by their height and weight the thrust upon their bases so obvious to the most casual observer. The Levensau Bridge[1] over the same canal affords another graceful example, though here the impression of lightness is somewhat marred by the interference of the road-way girders with the crown, and also by the greater depth of rib near the springing. The three-hinged arch has not hitherto found so much favour as the arches above mentioned. The Alexander III Bridge in Paris, Fig. 31, is the latest example of this construction, and it must be admitted that its adoption in this instance has been attended with signal success. It is true that the rib has a fairly uniform depth; yet, far from the points of articulation being screened, a practice so often followed in examples of the two-hinged arch, they have been appropriately made a prominent feature in the design. The general impression created by this structure is one of great elegance, and this is the more satisfactory when the exceptional restrictions placed upon its design are fully weighed. If it possess a fault, it is that the masonry pedestals at its approaches are a little too high for so flat an arch, and are situated a little too far in rear of the visible recipients of the thrust; their position, in fact, scarcely renders them liable to criticism as a legitimate part of the structure.

Turning to the connections between the platform and the arch, reference to Figs. 32, 33, 34 and 35, will show that these are of very varied character. Where the platform passes above the arch, they are either piers, as in Figs. 34 and 35, or a series of bents, as in Fig. 32. The piers in Fig. 34 are, from their parallel outline,

[1] Minutes of Proceedings Inst. C.E., vol. cxxxvi. p. 374.

certainly not so pleasing as those in Fig. 35, which, incidentally, is almost identical in outline with the first arch erected over the Douro. The difference in the bracing of the land piers of Fig. 34 also detracts from its successful æsthetic effect. It would seem desirable too, so far as is possible, to maintain some degree of similarity between the bracing of the arch and that of the piers. In Fig. 32 the effect is unpleasing; the spandrel-filling is so severely rectangular as to be antagonistic to the triangulation of the rib, and to suggest an importation from an entirely foreign design. An equally unsatisfactory feature is the absence of a more emphatic support beneath the outer ends of the bowstring spans. At the landward end their stability is evident enough; but at their connection with the central span they have all the appearance of resting upon a member which, along with others similar, seems wholly required for the support of the roadway above the arch. In the actual bridge the rectangular panels are of course provided with diagonal braces; but these are so slender in comparison with the more pronounced vertical and horizontal members, that the general effect is practically that represented by Fig. 32. The two landward spans also differ appreciably in length, and it is doubtful whether the inverted curves of the bowstrings are the most appropriate for harmonising with the upright curve of the arch. It seems a matter for regret that this largest and most recent example of the large-span metal arch should not have received a little more æsthetic consideration. In any reference to the elevational view of a structure as a means of forming an estimate of its general appearance, it must be borne in mind that an adequate impression of its æsthetic value frequently cannot be thereby acquired; and allowance should accordingly be made for the difference between the appearance of the design on paper and that of the work itself. Especially is this so in those structures in which, from the great width of roadway required, it is necessary to employ several parallel trusses or ribs, in which case the resulting perspective effect due to repetition may considerably add to the value of the design. What the elevation of a structure does show, however, is the extent to which any of the primary laws of æsthetics may have been violated. Another feature peculiar to many examples of the metal arch, which cannot be adequately shown on other than a perspective view, is the graceful effect created by the batter on the two main ribs.

Where the roadway is carried wholly or partially below the crown of the arch, tension members are required, instead of

struts or piers; and the former being of so much lighter section, conduce largely to the increased grace of these structures.

The platform-girders and parapets of bridges such as those under consideration are little subject to variation in design, consisting essentially, whatever be the mode of support, of a suitable continuous lattice girder, which rarely produces other than a satisfactory effect. They are consequently little open to criticism, the principal point being to ensure their having the requisite degree of lightness.

Reference may finally be made to lofty viaducts in iron and steel, which are carried over deep valleys on built-up metal piers. By reason of the height of these structures, the piers are necessarily of a more or less pyramidal shape, severely rectilinear as regards bracing, and accordingly produce in the mind of the beholder a satisfactory impression of stability combined with lightness. The diagonal bracing of the piers may generally be arranged to harmonise well with that of the girders, and this type of structure seldom offends good taste.

Combined Masonry and Metal Bridges.

Most of the bridges remaining for consideration fall within the third class, constituting as they do various examples of the supported girder carried upon masonry piers of such prominence compared with the superstructure as to exert an appreciable influence upon the æsthetic appearance. This class of structure is typified by such bridges as the Britannia, Runcorn, and Saltash, the High-Level Bridge at Newcastle, and many suspension bridges. In these cases the important part played by the high masonry piers in relation to the tasteful appearance of the structure is apparent at a glance. Judging from the existing examples, it seems advisable to exclude strictly from their design anything suggestive of established architectural ornament. The piers of such bridges so little resemble, in either dimensions or shape, anything encountered in every-day construction, and their appearance is often so affected by their environment, that their effect is most pleasing when a simple but massive treatment is adopted in their design. The Britannia Bridge, Fig. 37, Plate 3, makes no pretension to architectural beauty, yet a greater æsthetic success has seldom been achieved. The piers are devoid almost to meanness of architectural detail, but their appearance conveys a striking impression of majesty. Their severely rectilinear outline and mass especially harmonise with those of the tubes, whilst the happy

inspiration of carrying up the piers to a considerable altitude above the girders adds greatly to the effect, by a suggestion of continuity in the latter, due to the perforation of the piers by them. The design is peculiarly favoured by the natural grandeur of its surroundings. Contrasted with the Montreal example, the only other important tubular bridge ever erected and but lately taken down, its superiority is very marked; the greater length and ruder appearance of the Montreal piers detracting greatly from the design of that bridge. Had the piers of the Runcorn Viaduct been treated similarly to those of the Britannia Bridge, the general effect would probably have been heightened.

The High-Level Bridge at Newcastle, Fig. 38, despite its sordid surroundings, furnishes a striking example of what may be accomplished by the combination of two dissimilar materials in equally massive proportions. Here again, the masonry is strictly in keeping with the massive presentment of the superstructure. The same can scarcely be said of the Saltash example, Fig. 39, the piers of which are satisfactory in design, though their effect is slightly marred by the different form adopted for the central one. The overpowering mass of the upper member of the girders, however, is so little consistent with the exceeding lightness of the chains and bracing as to detract greatly from the pleasing effect. The same is true of Brunel's other bridge at Chepstow, only there the detraction is still more marked by the absence of any graceful curves. In the Hamburg example this objectionable feature is avoided, the upper and lower members of the girders being of similar outline.

The Menai Bridge, by Telford, Fig. 40, is almost outside the pale of æsthetic criticism. In addition to its possessing the grace of form inherent in all suspension bridges, the appearance of the land arches is especially acceptable on account of their exceeding beauty of proportion. It has been objected that the piers, from certain points of view, seem a little overdone in the matter of stability: that this is due in great measure to their cellular construction is, of course, well known, and there is certainly very little modification in their external design to suggest that they are not of solid masonry throughout. The existence of considerable hollow spaces in these and in many other lofty piers cannot be sufficiently realised in passing judgment upon their external appearance; and the impression created may be one of extreme heaviness, unless the design presents something to suggest the contrary: probably well-marked recesses or panels left on the inner faces of such piers would best meet this requirement. It should be remembered that

in the example under consideration the piers are required to act as efficient abutments for the landward spans, in addition to supporting the main structure.

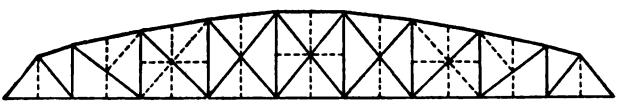
As to the suitability of combining masonry structures of distinct architectural pretensions with the structural steel or iron work of a bridge, very wide difference of opinion will always exist. Here, as indeed throughout the whole subject of æsthetics, each individual forms his own impression, and such impressions are oftener dissimilar than alike. The main point at issue appears to be whether or not it is justifiable to employ a considerable amount of extra material, often of a different nature, solely for purposes of ornament. Where such material would have to be carried by the structure, there can be but one opinion; but that the aid of architectural embellishment may be successfully employed in beautifying strictly engineering structures has over and over again been amply demonstrated. Mention has already been made of the especially pleasing effect of the use of masonry towers in connection with the metal arch, in which case the towers perform the double function of aiding to resist the thrust and of improving the appearance of the bridge. Eminently successful examples of this occur in the bridges over the Baltic Canal, and over the Rhine at Bonn, Düsseldorf and various other places. In the Tower Bridge,[1] ornamental masonry is equally successfully applied on a still grander scale for partially hiding as well as beautifying what would otherwise present a much less acceptable appearance.

This portion of the subject cannot be made in any sense complete without some brief mention of the treatment accorded to the many prominent and visible details of medium and short-span bridges usually carried upon masonry piers. The majority of these structures can lay very little claim to æsthetic effect; yet, by the exercise of a little additional care in their design, the lack of it may be rendered much less noticeable, and their comparative value be thereby increased. It is a matter for congratulation that the sharp-featured parallel girder is, in this country at least, gradually giving place to the lattice bow similar to that employed in the Kuilenburg[2] and Newark Bridges, which, apart from the question of economy, has a much more pleasing appearance when used for a single span. This superiority is not so marked in the case of a longer bridge with several spans, the parallel girder being more suggestive of the idea of continuity, especially

[1] Minutes of Proceedings Inst. C.E., vol. cxxvii. p. 35.
[2] *Ibid*, vol. lxiii. p. 155.

when the ends are masked by an upward continuation of the pier masonry. The type of lattice girder particularly affected in American practice, by reason of its being usually pin-jointed, is not so pleasing in appearance; the many redundant members introduced for stiffening the long and slender struts tending especially to hide the simplicity of the primary bracing. The rather promiscuous effect so produced is indicated in *Figs. 41* and *42*, respectively elevations of the trusses of the Merchants' Bridge over the Mississippi and of the Hawkesbury Bridge[1] in

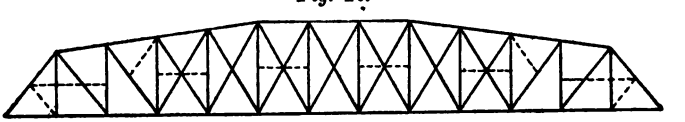
Fig. 41.



Truss of the Merchants' Bridge over the Mississippi.

New South Wales. The relative width of the various members seen on the broadside view of a girder goes far to produce an appearance pleasing or otherwise; by the exercise of a little forethought in designing the lattice members, their sectional area may be so arranged as to present a breadth in elevation which will harmonise with that of the booms. All are familiar with examples in which the booms appear too heavy for the bracing, and vice versa. Where an abrupt change takes place from a deck to a through span, a slightly better effect is produced by

Fig. 42.



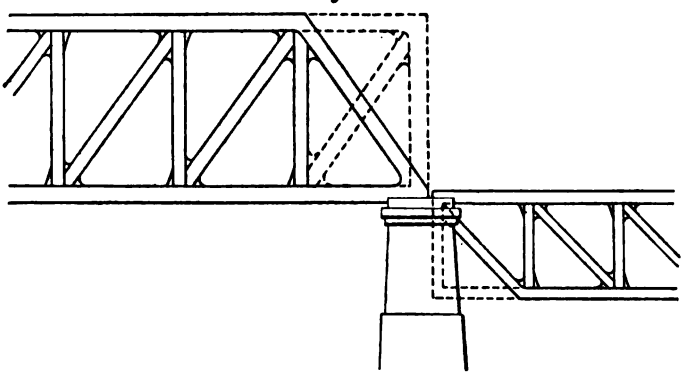
Truss of the Hawkesbury Bridge.

arrangement of the members as shown by the full lines in *Fig. 43*, instead of the dotted; here American practice has the advantage, the dotted lines representing really redundant members. The bowstring girder also is generally more pleasing in outline than the parallel form. By rounding the upper corners of parallel girders and introducing curved gusset-plates, a much more finished appearance is secured than when these details are left severely square or angular. A striking example of what may be accomplished in this way occurs in the railway bridge over the Wear at

[1] Minutes of Proceedings Inst. C.E., vol. ci. p. 2.

Sunderland, *Fig. 44.* The bowstring girders are provided with strongly-curved gusset- or web-plates in each corner of the panel, instead of the usual form of bracing. The stiffening effect is substantially the same as would be obtained with straight-line bracing, whilst the æsthetic appearance is distinctly superior. This example is quoted not necessarily as a suitable precedent to

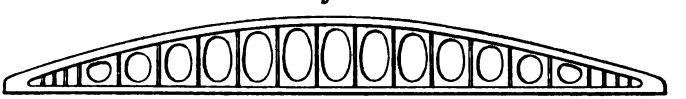
Fig. 43.



follow, but rather as one in which æsthetic considerations have perhaps been allowed to over-ride simplicity of construction.

The girders of still smaller spans usually consist of plate-girders, or of lattice girders with single or double triangulation. When of less than a certain depth, or when employed for deck bridges, they require some form of parapet or parapet-girder to be

Fig. 44.



RAILWAY BRIDGE OVER WEAR, SUNDERLAND.

erected above them. The parapet is then obviously a prominent feature in the broadside view of the structure, and its design goes far to make or mar the general appearance of the bridge. With lattice main girders in deck spans the most suitable form of parapet-girder to be employed will be a lattice girder proportionately lighter in design. Very satisfactory examples of such are afforded by several of the deck bridges recently erected on the new Great Central Railway main line.[1] It is in relation

[1] Minutes of Proceedings Inst. C.E., vol. cxlii. pp. 1 and 23.

to the plate-girder, however, that the most noticeable offences against good taste have been committed. It is no uncommon occurrence, where plate-girder spans are erected across busy city streets, to find not only the webs of the girders decorated with iron mouldings, stars or other emblems, but, surmounting these, a second array of panels of an equally florid nature, masquerading as a parapet, the whole structure, as often as not, resting on a series of grossly misproportioned classical pillars in cast iron, and distantly resembling the entablature of a Grecian colonnade. Especially is this aggravated when, as indicated in the left-hand half of Fig. 45, Plate 3, the main-span girders have a curved upper flange, whilst the parapet is sliced off to a horizontal line in continuation of the upper edges of those of the side spans. Fig. 46, taken from a recently erected structure, indicates a pleasing departure from the use of the classical iron pillar for the support of low-level girders. It is constructed entirely in structural steel, and at any rate has the merit of not suggesting anything in the nature of a masonry precedent.

Finally, the Author proposes to notice briefly a few examples of the application of cast-iron ornament to the decoration of metal bridges. The special situations in which this style of treatment is distinctly called for are generally those where bridges are erected in prominent positions in or near important streets; but it should be remembered that, unless the dignity of the surroundings expressly demands it, the application of such ornament, being at variance with the primary laws of economy, will be equally at variance with the principles of æsthetics. Where cast-iron decoration is adopted, it should be applied so sparingly as to produce the best effect with the least expenditure of material, since every ounce of material lavished on unnecessary ornament places so much detrimental weight upon the structure. Numerous examples occur in which a moderate use of this material with a little more care in its design would have produced a much more pleasing result. Every detail of the ornament should be appropriately matched, and unless classical proportions are rigidly observed, masonry prototypes are best left alone. Everyone must be familiar with examples of the arch in which the design of the spandrels follows some line of treatment in geometrical tracery or Gothic ornament, whilst that of the parapet pursues a widely divergent course in the direction of severely rectilinear detail, and vice versa. Again, anything resembling an ornamental keystone at the crown of an iron rib,

by interrupting the continuity so essential to a true conception of its strength, is especially detrimental in effect. Nowhere has this material been so abused as in its application to the construction of the pillar. The majority of iron pillars in engineering work are either too squat or too slender; whilst the servile imitation of severely classical and lithic detail contributes only to a still more painfully ludicrous appearance. It seems indeed a pity that those responsible for the perpetration of these and similar designs should not have made a sufficient study of architecture, less with a view to its employment than to learn when not to use it.

A minor feature in this matter is the confusion frequently arising from the combination of some fairly suitable design of cornice around the tops of cast-iron cylindrical piers, with a distinctly inappropriate form of bracing between the pillars themselves. A fairly successful example is shown in Fig. 47, Plate 3, which may roughly be compared with Fig. 46; the straight line bracing of the latter, whilst satisfactory in its particular case, would be obviously out of keeping in the former.

It must be apparent to the ordinary observer that the most striking æsthetic successes have been achieved where cast-iron ornament has been applied in the decoration of metal arches of small or medium span. No more pleasing examples of this can be cited than the Great Western Road Bridge at Glasgow, the new North Bridge at Edinburgh, and the Alexander III. Bridge at Paris (Fig. 31). In the first of these, success has been primarily ensured by the careful proportioning of the side to the central arches; whilst the all-important feature of the ornament is the harmonious blending of the geometrical tracery in both parapet and spandrels, and the perfect agreement of these with the Gothic pillars adopted for the faces of the piers. In the Edinburgh example an entirely different note is sounded with equally successful effect. Here the treatment is severely classical; and although the steep inclination of the roadway somewhat detracts from the general appearance of the structure the æsthetic effect is one which emphatically pleases. In both these examples the ornament is carefully subordinated to the prominent structural feature of the bridge, the arch in each being strongly accentuated by heavy mouldings, the employment of which is generally more successful on the iron than on the masonry rib. In the third example a classical idea is also followed out; but here the open spandrels produce a heightened effect of lightness absent from the other two, whilst the surroundings are also considerably more favourable to the formation of a proper estimate of its æsthetic value. It is to be regretted that the

amount of ornamental detail in the Glasgow and Edinburgh examples renders them unsuitable for illustration on a small scale; but they are fortunately so well known that this omission may be overlooked.

In conclusion, the Author would observe that he makes no claim to have presented, in this Paper, an adequate treatment of a far-reaching and important subject. He hopes, however, that the various points considered may not be devoid of interest to those concerned with the design of engineering structures.

He desires to acknowledge his indebtedness to the "Minutes of Proceedings" of the Institution, to the "Annales des Ponts et Chaussées," and to the leading English, American and Continental journals, for many of the illustrations appearing in the Paper.

The Paper is illustrated by 47 drawings, from which Plates 2 and 3 and the Figures in the text have been prepared.

APPENDIX.

Dimensions have been purposely omitted from the Figures, and the following Table supplies the leading dimensions of the bridges referred to:—

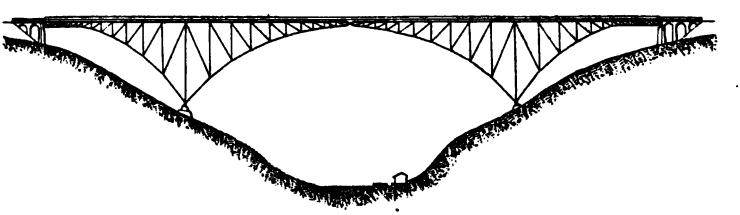
Number of Figure.	Bridge.	River.	Number of Spans.	Span.		Rise.	
				Feet.	Ins.	Feet.	Ins.
2	Grosvenor	Dee	1	200	0	42	0
11	Cartland Crags . .	Mouse Water	3	52	0	26	0
12	Dean	Water of Leith	4	90	0	30	0
19	St. John's River . .	St. John	1	477	0	..	
20	Poughkeepsie . . .	Hudson	3	548	0	..	
21	Forth Bridge . . .	Firth of Forth	2 Central	1,710	0	..	
,,	,, ,, . . .	,, ,,	2 Side	690	0	..	
22	Sukkur	Indus	1	820	0	..	
25	Jubilee	Hooghly	1 Central	120	6	..	
,,	,, ...	,,	2 Side	540	0	..	
26	Borcea	Danube	1 Central	459	0	..	
,,	,, ...	,,	2 Side	456	0	..	
31	Alexander III . . .	Seine	1	353	0	20	9
32	Niagara Falls & Clifton	Niagara	1	840	0	150	0
33	Grünenthal . . .	Baltic Canal	1	513	6	78	6
34	Müngsten	Wupper	1	560	0	250	0
35	Garabit	Truyere	1	541	0	196	9
36	Bonn	Rhine	1 Central	616	6	105	0
,,	,, ...	,,	2 Side	310	0	26	3
37	Britannia	Menai Straits	2 Central	460	0	..	
,,	,, ...	,,	2 Side	230	0	..	
38	High Level, Newcastle	Tyne	6	138	0	..	
39	Saltash	Tamar	2	455	0	..	
40	Menai Suspension. .	Menai Straits	1 Central	580	0	..	
,,	,, ,, . .	,,	7 Arched	52	6	..	
41	Merchants' Bridge .	Mississippi	3	521	0	..	
42	Hawkesbury . . .	Hawkesbury River	7	416	0	..	
44	Sunderland Railway Bridge	Wear	1	300	0	..	

Discussion.

The President. The PRESIDENT observed that the Paper was rather different in scope and character from those which the members were accustomed to hear read and to discuss at the Institution; but the Council had had no hesitation in accepting it, both because it was an interesting Paper in itself, and because just at the time when it had been under consideration, a suggestion had been put forward by the Royal Institute of British Architects that an endeavour should be made to devise some mode by which the Institution could collaborate with that body in the designing of important bridges crossing rivers such as the Thames in London. The Council had not seen its way to offer any practical suggestions in that respect, but it had invited to the Institution that evening members of the Royal Institute of British Architects, and he hoped that some of them would take part in the discussion. He thought a good discussion on the Paper should ensue, and he was sure the members would agree with him that a hearty vote of thanks was due to the Author for his instructive and interesting communication, and for the great trouble he had taken in preparing so many diagrams.

The Author. The AUTHOR exhibited a number of photographic views of the various bridges. He also showed the elevation (*Fig. 48*) and a perspective view of the viaduct over the valley of the Viaur in

Fig. 48.



VIAUR VIADUCT.

the South of France, a structure chiefly interesting as being the largest three-hinged arch erected down to the present time, and the second largest steel arch in existence. The central span

measured 721 feet 9 inches, and the height of the rails above the lowest point of the valley was 380 feet. He directed attention to its æsthetic value as compared with the Niagara Falls and Clifton Arch. The chief difference in appearance occurred in the spandrel-bracing. In a Paper[1] read at a recent meeting of the Institution, Mr. Buck, the engineer of the latter bridge, had acknowledged a preference, on æsthetic grounds, for the large-span arch with diagonally braced spandrels, rather than for one of the Niagara type. He hoped that other valuable expressions of opinion might be elicited as to the relative merits of the two bridges. The Author.

Mr. W. EMERSON, President of the Royal Institute of British Architects, remarked that it was a great privilege to have the opportunity of hearing so interesting a Paper, and he would like to tender his quota of thanks to the Author. He also thanked the President and Council of the Institution for their kind invitation to him to be present that evening. The Author had put before the meeting a large variety of designs of bridges which he did not propose to follow in detail; nor did he intend to trouble the members with any remarks as to how those bridges, which for the most part were of a purely utilitarian character, could be treated in a more æsthetic manner. He wished, however, to say a few words on the general question of the necessity for more æsthetic treatment of bridges in large metropolitan centres than was usually the custom at the present time. The Author had remarked that there were three fundamental points which tended to æsthetic effect; the first point was suitability to the exigencies of the case, the second, simplicity in design, and the third, proper treatment of material. The Author, however, had pointed those remarks by a sentence in his Paper in which he said, "Nowhere is this fundamental rule better exemplified than in Nature. A tree is undoubtedly one of the most beautiful of natural objects; yet even to the least trained mind it is apparent at a glance how stability is assured by the splaying out of the roots around its base, and a perfect balance is obtained by the shooting of the branches in every direction; whilst the decreasing girth of the rising trunk provides exactly the diminishing strength required for resisting the pressure of the wind and for carrying the weight safely." He thought the Author had hit off in that sentence the first element of æsthetic effect, but he had not carried his simile far enough; he had stopped just short of the mark. Not only in a tree, but in Mr. Emerson.

[1] Minutes of Proceedings Inst. C.E., vol. cxliv. p. 71.

Mr. Emerson. every work in Nature, whether tree, plant, or animal life, there was perfect construction, exactly suited to the requirements of the case. But that was the skeleton, and in many respects that skeleton appealed to a man's logical brain-power, and in a way might be beautiful. The bare skeleton of a man was so. In that way also works like Charing Cross Bridge, the Eiffel Tower, or the Forth Bridge appealed rather to the brain-power; but Nature went a step further. He took as an example the proverbial lily, which answered its purpose from the constructive point of view exactly the same as a tree; it had a firm foundation, and its stem and leaves were suited to resist the elements. But there was One who had said, "Even Solomon in all his glory was not arrayed like one of these;" and he took it that that raiment of the lily meant something entirely apart from and far beyond its structure. It referred to its æsthetic effect—its beauty. There were two distinct elements—the constructional and the æsthetic. It was true they grew up together, and were part and parcel of each other, but the one was entirely different from the other. He thought that principle should apply also to such public works as bridges, and it might equally apply to other public works in large metropolitan centres or the big cities of the world. He did not think æstheticism could be carried to any great extent into purely utilitarian works like bridges of enormous span in the country, but it seemed to him it was an important thing that in larger metropolitan centres the bridges should have both those elements in them; not merely the constructive element to appeal to the brain-power, but also the æsthetic element which, in the present age of high intellectual culture and educated taste, should appeal to the eye. Man, however, had no instinctive creative faculty, neither was he perfectly acquainted with every rule of constructive science, or every rule of art. It took an engineer the greater part of his life to become a master in his science, and it took an architect or an artist the whole of his life to learn something of art. It therefore seemed somewhat unreasonable to expect that any one man, whether an engineer or an architect, should be able in the present days of concentration of energy to carry out a work such as a very large bridge with perfect scientific skill and perfect æsthetic taste. That feeling was prevalent not only in this country but in most parts of the civilised world, certainly in America, France, Austria and England, and he fancied, from looking at the works of olden times, that it had been prevalent in ancient days also. At the present time a very good example was afforded by the Alexander III. Bridge in Paris. It would seem

that if an engineer or an architect was not equal nowadays to dealing with both sides of the question there should be some collaboration between engineers and architects. There had been a good deal of discussion about the necessity of collaboration between architects and sculptors and painters, and he thought all would agree that there was absolute necessity for it. In the Alexander III. Bridge two engineers and two architects had been employed, and they had managed to work amicably; and he thought everyone would agree that the effect of that bridge was better than usual. In America it had been the custom for some time for architects and engineers to work amicably together in constructing buildings, both public and private; he understood the same steps had been taken in Vienna. With regard to ancient times, could it be supposed that the magnificent viaducts and aqueducts of Rome were built entirely by engineers? There must have been some artistic element in them as well as constructive ability. Again, supposing the bridge at Prague had been constructed purely on engineering lines, and had been devoid of its magnificent architectural approaches and adornments, he thought the loss to the world would have been inexpressible. In this country, however, there appeared to be certain difficulties in the way of collaboration between engineers and architects, and he could not help thinking that those difficulties were purely suppositious. From what he knew of engineers and architects, he would imagine they could, if they chose, come to some arrangement by which they could work very amicably together; but inasmuch as in Nature—in the lily, for example—the æsthetic effect grew up from the very commencement with the constructional design, so, in such a work as a bridge, it would be absolutely necessary for the architect to work with the engineer from the very inception of the work. It would be useless to cover a bridge with a veneering of architecture, or, after having designed a bridge, to simply clap on architectural ornament. The whole thing ought to be worked at from the commencement with considerable thought on the part of both engineer, architect and sculptor, and then carried out under their united supervision until it matured into a perfect work. He sincerely hoped that the day was not far off when, in towns like London, or large provincial towns, where the imperial character of the nation was at stake, municipalities and others, who had to initiate such works as bridges, would see the necessity for collaboration between engineer and architect; and he felt quite sure, that when such a stage was arrived at, England would not be far behind other countries in the

Mr. Eme

Mr. Emerson. æsthetic effect, not only of her bridges, but of her other public works.

Mr. Rennie. Mr. G. B. RENNIE agreed that the collaboration of architects with engineers was no doubt very important and, if it could be carried out, very desirable; but in a large engineering structure the architect would have to give way, in a great measure, to the engineer, because it would fall mainly upon the engineer to arrange the form of construction suitable for a particular site. Moreover, he thought it would be very difficult for an architect, in such structures as many of those referred to in the Paper, to improve the æsthetic effect to any large extent. No doubt collaboration in the case of the Alexander III. Bridge had produced a charming and beautiful effect; anyone who had seen the bridge would feel that. It should be remembered, however, that that bridge had been built for a particular purpose, viz., to connect the Fine Art buildings of the Exhibition with the rest of Paris. Therefore a thoroughly architectural design had been very suitable in this case. The bridge might be considered to be too ornamental for an ordinary engineering structure, but the whole structure was so pleasing that he thought it could be said that in such cases the architect might very well collaborate with the engineer. In London, as the President of the Royal Institute of British Architects had well said, it was very important to have a bridge with an architectural effect. The bridges which had been built by members of his family—Waterloo Bridge, Southwark Bridge, and London Bridge—had such an effect. Now it seemed that people were not satisfied even with the effect of those bridges as they were. In the case of London Bridge, some years ago it had been proposed to take away the present parapet and cornices, and to substitute corbels or iron cantilevers. That had been strongly objected to, and Messrs. Horace Jones and Charles Hutton Gregory had reported in 1875 that that system was utterly unsuited to the bridge. The proposal to add iron arches instead had come before Parliament in 1879, and had been very nearly passed, but through the influence of Lord Carnarvon it had been referred to a committee, and it had been absolutely condemned as unsuited to the bridge. The leading artists and architects of the time had given evidence against the general æsthetic effect of the iron additions, and so the Bill had been thrown out. At the present time it was reported that the old idea of corbels or iron cantilevers was being revived, but he hoped architects would try to prevent it from being carried out, as it would certainly spoil the whole appearance of the bridge.

He believed there was also some idea of widening Waterloo Bridge in the same way. He had not seen the design, but he thought that any alteration of the structure would absolutely spoil it. London Bridge had been built by his uncle, Sir John Rennie, who had strongly condemned any additions to its architectural features. With regard to structures of large span, such as were indicated in the Paper, he was inclined to agree with Mr. Emerson, that it was almost impossible to improve their general appearance. In the case of the Britannia Bridge, there was a grandness of design, a simplicity, and a situation which produced a very fine effect altogether; whereas Conway Bridge, a low squat bridge of similar construction, had a most damaging effect on its surroundings, and nobody could say there was any beauty in it. Mr. Rennie.

Mr. W. D. Caröe wished, as an architect, to say a few words on the general subject. Mr. Emerson had said almost all that could be said on the question of the collaboration of architects and engineers in bridges of an architectural character. He thought the Author had been a little severe in dealing with early engineers in the opening words of his Paper, where he had expressed the opinion that they had not considered the æsthetic side of the question. His own feeling was rather the reverse. It was a great pleasure to him to be able to express amongst engineers the pleasure and satisfaction that some engineering structures had given him, and if he might mention a few he would put first the Menai Bridge, the effect of which was very much the same as that of one of the finest cathedrals. It was so elegant and so excellent in its proportions and details, and so admirably suited to its use and to its surroundings, that he felt he was standing before a work of genius. Again, with regard to its neighbour, the Britannia Bridge, he thought the Author was not quite fair; he praised it, but he praised its lack of architecture. It appeared to him that it had a very strong architectural flavour, and that it possessed one feature in a marked degree, which the Author had entirely ignored in his Paper, and that was the quality of architectural scholarship. It was precisely that quality of architectural scholarship, which took an architect his whole life to learn, that was missing in so many of the bridges which engineers produced. He did not think any blame attached to engineers on that ground, for, as Mr. Emerson had well said, the application of their time and opportunities lay in another direction. The Britannia Mr. Caröe.

Mr. Carëe. Bridge appeared to him to be altogether admirable in that respect. It was the work of a master, and he would much like to have seen it illustrated on the walls on a larger scale, because it was just such a construction that ought to be considered in detail in respect to the æsthetic treatment of bridges, and which had not been considered in the Paper. Again, there was the bridge at Budapesth, of which all Englishmen ought to be proud, which had been the work of an Englishman in the year 1851. It afforded a very remarkable instance of progress. Mr. Adams had built a very similar bridge at Shoreham 3 years or 4 years previously, and then he had won the competition for the bridge at Budapesth, and had produced one of the most remarkable works to be seen—a suspension bridge with admirably designed piers. The Forth Bridge filled Mr. Carëe with delight whenever he saw it, although he felt he was treading on rather delicate ground when he ventured in the presence of Sir Benjamin Baker to express the opinion that the land approaches were not quite equal to the large spans in character and design. The majority of the works of early masters might be studied with the greatest advantage in the matter of æsthetic construction of bridges. The main reasons why the four bridges he had mentioned gave him special pleasure, and were, in his opinion, worthy of great commendation, was that the engineering was excellent, the material being used to the best purpose; and that, so far as architecture went, the architecture was suitable, and even scholarly. As an instance of a different kind, he mentioned the Brooklyn Bridge at New York. That bridge had an excellent curve, and was in many ways, especially when seen in a mist, a fine structure, but its architectural qualities were irredeemable. There had been a foolish attempt to introduce a very shoddy form of Gothic architecture into the piers, which, to his mind, very much detracted from the whole conception. The Conway bridges had been referred to, and it had been stated that the chief interest of those bridges was their consonance and harmony with their castellated surroundings. It had always appeared to him rather remarkable that the engineers who had succeeded so admirably in the Menai Straits had failed so miserably at Conway; and the reason appeared to be that a sort of false sentiment was attached to the work, which, so far from being appropriate, was entirely out of harmony with the surroundings. Who in the world in these days would wish to protect a railway bridge or a suspension bridge from the inroads of an enemy by

putting up machicolations and arrow-slits? They were absurd, and, being absurd, they did not enter into the least harmony with Conway Castle, which was erected at a time when machicolations and arrow-slits had a proper and reasonable purpose. The whole subject was one of learning to use the materials correctly, with due reference to the occasion and the sentiments which surrounded it. With regard to the question of ornament as applied to bridges, he would be very sorry indeed to support in any way an idea which he was afraid was too often held, that architecture meant ornament. Architecture really meant nothing of the kind, and with regard to iron structures he thought it might be accepted as an axiom that when ornament walked in at the door Art flew out at the window. The Glasgow and Edinburgh examples appeared to him to be villainous. In the Paper a reference had been made to a successful masking of bridge structure with cast-iron plates or ornaments. He believed that the result of any attempt of that kind was certain to be failure. He had only to instance Westminster Bridge—which, he considered, might have been a pleasant and agreeable structure, but was quite spoiled by the architectural adornments which had been added to it. He could not help feeling that it was possible to arrange a workable scheme by which architects and engineers could work harmoniously together, with great benefit to the works produced. Architects could not pretend to produce engineering works, or to obtain the advantages from iron which an engineer could do, and did so often. Some of the skeleton bridges shown on the wall gave him the very greatest pleasure. There was no architecture connected with them, except that architectonic feeling which was obtained from all work rightly and scientifically constructed. In conclusion, he thanked the Council for inviting him to be present, and the Author for the charming manner in which he had placed so large a collection of bridge designs before the meeting.

Mr. Carde.

Mr. F. E. Robertson thought it was scarcely right to introduce the Paper with a sort of apology for its being something out of the ordinary way, because it seemed to him that to do so was to lay engineers open to an accusation which was frequently brought against them—and he was afraid not without some reason, having regard to the diagrams on the wall—that they either displayed a great deal of indifference to æsthetic considerations in the structure, or, which was perhaps worse, tried to conceal an ugly carcase under meretricious adornments. The Author quoted, as an apparent paradox between what was pleasing to the eye and what was necessary to the structure, the cut-waters up and down stream

Mr. Robertson.

Mr. Robertson. on the pier of a bridge; he was quite right in saying that they were pleasing to the eye, but he omitted to consider that they were also necessary to the structure. A clean run was just as necessary to a ship as a fine entrance, and if the Author would study the action of a cylindrical pier in a large river, he would see that a cut-water at both ends was certainly necessary to obviate scour. The Author also remarked, apparently as an excuse for the neglect of æsthetic treatment, that the obstacles to be overcome in the manipulation and erection of large bridges in situations of extreme difficulty often precluded the adoption of a more pleasing design. He hardly thought that was the case, because one could easily find two similar bridges, one of a pleasing outline and another of a design not so pleasing, and certainly the former was not the least economical. He might mention in particular the Viaur Viaduct. There had been a large model of it in the Paris Exhibition, and to judge from that the structure was a very elegant one and certainly economical. That the difficulties of erection precluded pleasing outlines could hardly be accepted as a ground for putting up an awkward-looking structure. A familiar instance was that of an ordinary girder-bridge. The large Indian girder-bridges, with parallel girders, as a rule looked like nothing so much as magnified coffins set out on trestles; but such of the bridges as had been built with parabolic girders were certainly far better looking than similar bridges built with parallel girders, and the parabolic girders were the more economical of the two. Mr. Caröe had remarked, with reference to the Conway Bridges, that they were inappropriate on account of the attempt to convey the impression that they were fortified. He was not sure that Mr. Caröe did not go a little too far when he repudiated the idea of fortification altogether in connection with bridges, because in India all the large-bridge-heads were fortified; it was invariably a matter of consultation with the Military Department. Of course it was not inconceivable that the same thing might be desirable in England, and he believed it was often done on the Continent. [Mr. Caröe asked whether Indian bridges were fortified in machicoulis and arrow-slits?] They were fortified for musketry, not for heavy guns. They were built according to the requirements of the Military Department with loopholes and machicoulis. He did not know whether it was proposed to pour boiling oil and melted lead down on the enemy, but the machicolations were demanded.

Mr. Ricardo. Mr. H. Ricardo was cordially in sympathy with the principles laid down in the Paper. It had struck him, however, while the Paper was being read, that there was throughout a kind of dis-

trust of the position. Phrases had floated about such as, "This would mean good taste"—"This would succeed"—"This has generally been found pleasing"—"This might be done and this might not"—in fact, the shadow of Mrs. Grundy appeared to loom very large, with a fear of the "superior person" talking about "good taste." One element missing in the Paper was the emotional treatment of bridges, namely, the treatment of bridges from the point of view of sentiment and feeling. The word sentiment was open to many interpretations, but the Paper appeared to ignore even such an elementary sentiment as permanence. Sentiment contributed very largely to the beauty of things. Beauty was not extraneous, but inherent; it was a quality which came from a great knowledge of the materials, a wise distribution of them, and a certain fondness in the handling and fineness in the purpose. He might take as an instance a man standing by a ford and carrying people across pickaback. That man was doing a worthy service, but there was nothing inspiriting or particularly memorable in it. But if by chance a little child sprained its ankle and was carried over to the other side tenderly by the ferryman and handed over to people who would care for it, there had been imported into the action an element of pathos and humanity and of beauty. Again, taking a larger instance of the same thing, if it was anyone's business to, say, transport ten coach-loads of food from A to B, something was done which might be serviceable but was not memorable; but if, on the other hand, as constantly happened in India, for instance, immense viaducts were built for railroads to carry, in times of famine, quantities of food from a surplus store to where it was needed, a fine deed was done. Those were legitimate sentiments to import into the subject—sentiments based on the understanding of the function of the object. Beauty was talked of very glibly, but there was seldom any distinct statement to grasp. The canons of beauty were incessantly being enlarged. What was beautiful in the past remained beautiful, but its beauty was not that of the present time, under changed circumstances. He was old enough to remember connoisseurs of music complaining of Beethoven's later methods, and averring that if he had adhered to the pure simplicity and great beauty of Mozart his music would have been superior; but Beethoven had had something to say, and had said it, and now he had become a classic with his masterpieces of beauty. Then came Wagner, who also had much to say, and introduced a further element, which was instantly denounced as uncouth and barbarous; his dissonances were subjects of raillery, but

Mr. Ricardo.

Mr. Ricardo.

his work was now classic and his novelties were admitted as beauties. So in literature. Carlyle was a man with a gospel which he had to speak out, while the critics of the day declared that his style was ugly, vehement, turgid, and out of proportion; but he was now regarded as a master. So also in poetry. It used to be said that Browning was obscure, rugged, uncouth, but he had enlarged the conception of beauty. The same thing was being done by engineers. Engineers were enlarging what had been the canons of beauty. He regretted to see a certain admiration given to "architectural" book-learning, book-learning not merely as archæology, but as something which would enable a designer to apply to his bridge forms of beauty of past times. The "ornamentation" of the Great Western Road Bridge at Glasgow was an example. The haberdashery of architectural detail there had been stolen from work done at the time of the Wars of the Roses, and came from colleges and churches. It represented to anybody who really cared for such things, the masons' knowledge of his material, and his delight in dealing with it. The mason took his stone and used as little as he could, consistently with the purpose he had in view, and then, having enjoyed doing the work, he could hardly keep his hands off it, and elaborated it out of love for his work. But it was mason's work and mason's handicraft. The moulding applied to the steel rib might be referred to as an instance of utter misconception of the history of mouldings and their consequent beauty. Originally, when a mason wanted to put a rib across a space, he used a squared stone, and nobody could want anything better; but it was found that on the scaffolding, with clumsy men about, the stone was liable to get bruised and chipped, and so the next step was to chamfer the edge. That gave two edges liable to be damaged instead of one; but they were broader, and bore the hurt better. Very soon it was found that it was better to have a roll and a hollow, because the roll would take the injury and not show it. Hence, in bridge masonry, as a rule those two forms only would be found, the chamfer, and the roll and hollow. Therefore, the enrichment on the Glasgow Bridge was wrong, on the ground, firstly, that it was not made of stone, but iron; secondly, that it did not represent handicraft, but mechanism; and thirdly, that it did not represent any particular pleasure taken in the production of the thing, but a kind of feeling that Mrs. Grundy would desire such a structure. Again, this lack of reverence for the material diminished the life of the structure, because it made it more difficult to paint. The painter's brush could hardly get into all the crevices, but the

damp would. So that, from the point of view of Art, he thought it might be safely said that, Art being man's message to man, and beauty being the bloom that came to things honestly and sincerely worked, one must expect beauty to come from pride in the material at hand, and by the passion of the worker. That it would come from that did not always follow. There had been periods in the world's history, especially in England's history, when people at large sought for beauty, as shown still in the minor arts, where left untouched: the ordinary hand-plane of a carpenter was still a very pretty thing, as was the ordinary farm-wagon as it went across the field. But he thought the present time was not such a period. Often sentiments of space, grandeur, force, and so on, were found in a structure, but beauty was curiously absent. Every new lamp-post put in the streets of London was an added terror, and at the present moment the artistic mind was shuddering at the thought of what might be coming in the new postage-stamp. Beauty could never be obtained self-consciously; it could only come from the material and the pleasure of handling it. He thought the best thing to do was to keep to the firm ground the Author had started on, which he would like to have seen him tread a little more boldly. Mr. Ricardo.

Mr. R. Elliott Cooper remarked that, when he had first glanced at the Paper and the illustrations, he had really thought that the object of the diagrams was to illustrate how very far engineers had strayed from æsthetic beauty. He did not for a moment mean to say that the definition of æstheticism given in the Paper did not quite conform to what should be understood by that name, but it certainly seemed to him that, although no one could doubt the utility of the structures illustrated, it was difficult to see where their æsthetic beauty came in. A great many of them were designed in such a manner that their fine lines fulfilled the idea of the usefulness of the material used and of the structure as completed; but where engineers in England failed to a considerable extent in comparison with continental practice was that, without in any way detracting from the structures themselves by any meretricious ornament, they very often failed to make the abutments and approaches to the bridges as effective as they might be. He could not see why, because a bridge was of large dimensions and of a certain form, it should be impossible to decorate it, or why the abutments and the general approaches to the structure should not in many cases be made more effective than they were. Anyone who had seen the great bridges of the Continent—such, for Mr. Cooper.

Mr. Cooper. instance, as the bridge over the Rhine at Cologne—must have been struck by the fact that the steelwork was not in the least degree decorated, but the approaches and the abutments were of a decorative character. With regard to the bridges illustrated in the Paper, as he had said, their usefulness was admitted. The Sukkur Bridge (Fig. 22, Plate 2) was practically a crane on one bank and a crane on the other, with a level girder between. No doubt it was a very remarkable work and served its purpose, but he did not see much æsthetic beauty about it. The Jubilee Bridge to his mind was still less an æsthetic structure; the centre girder, which practically served as abutments for the side girders, although exceedingly economical and perfectly scientific, could not possibly be called a beautiful object, nor could it be said that it did anything more than serve its purpose. He thought the various points brought forward by the Author had not had due recognition. For instance, the Author stated what he considered to be the reasons for the adoption of different designs, and why one was better than another. Reference was made in the Paper to two bridges of a very common form—bridges which engineers connected with railways had frequently to build—with three arches over a railway cutting. How it could be suggested that *Fig. 6* could be compared with *Fig. 7* for anything approaching prettiness of appearance he could not imagine, because it was manifestly wrong to have the side arches of a different curve from the centre one. It gave a most curiously hollow appearance to the centre arch, and he had never seen such a bridge built. Then with regard to tall piers, the Author considered that the one shown in Fig. 9, Plate 2, was very much more effective than the one with the straight battered face; that Mr. Cooper did not agree with. He thought the simple, battered face was far better than the curved face; and in a viaduct of that height it was much better to do away with the springers altogether, and to let the semi-circular arch come down to a tangent with the pier, rather than to build it in the way shown in the illustrations. Another point mentioned by the Author was the practice of carrying up cut-waters to the parapet. He thought that greatly detracted from the appearance of any bridge, especially a high one. If the parapet was broken up by pilasters corbelled out from underneath the string-course or cornice, the effect was far better than carrying up the pilaster between the springer and the cornice. That applied equally to Fig. 13 and Fig. 14. In both those cases, particularly Fig. 13, if the voussoirs had been continued until they met in the centre, without the interposition of the pilaster, the effect would have been much better. Those

were, of course, practical points which all engineers had more or less to deal with every day, and they were the views that appeared to him to govern even the ordinary works of construction shown in the diagrams. But turning to the larger works, it would be impossible to decorate the girders themselves. It might be possible, however, to add something to the approaches and the abutments, so as to give a more imposing appearance to the work as a whole. With regard to the question of the collaboration of an architect with an engineer, raised by the President of the Royal Institute of British Architects, Mr. Emerson and he had placed in the room a drawing of a bridge which they had designed together, simply as an instance of the fact that architects and engineers could work together without quarrelling as to which part the one or the other should take. A bridge of the suspension form lent itself more easily to decorative purposes than almost any other kind, and that was the reason why the suspension form had been adopted in that bridge, which had been designed for crossing the Tiber at the Piazza del Populo. It had also to serve as a memorial to King Victor Emmanuel. The decorative portions did not detract from the general engineering effect, and the towers afforded the opportunity of showing in sculpture the various incidents in the life of the king. Mr. Emerson having been too modest to refer to the picture as showing an instance where an architect and an engineer had worked together, Mr. Cooper might perhaps be excused for referring to it. He had also put on the wall a diagram (*Fig. 49*), showing a bridge in which æsthetic beauty was lacking. It was a bridge he built about 20 years ago over the Blaau Krantz Ravine in South Africa. The idea of the bridge was simply that of two men leaning forward with their hands joined. The necessity for building such a bridge arose from the almost impossibility of erecting staging, as to get timber to the site would have cost nearly as much as getting the steelwork there. The bridge had to be built without scaffolding, except the poles which were used for the painting and the staging for riveting up the girders. In the sense that æstheticism simply meant using material in a form most economical and best adapted to its purpose, he might almost claim that that bridge was æsthetic, but he could not put it forward on the ground of its appearance. It was an instance of what could be done with an end in view, without any idea of beauty. It should be remembered, however, that bridges looked very different when viewed at their sites. The large number of different lines and angles made them look much better than they appeared

Mr. Cooper.

Mr. Cooper. in diagrams. Bridges, which were almost hideous when shown in elevation on paper, when actually viewed looked very fine. That was the case with the Blaau Krantz Viaduct. Seen from the valley below it was very graceful, although its appearance on the wall would not have suggested it.

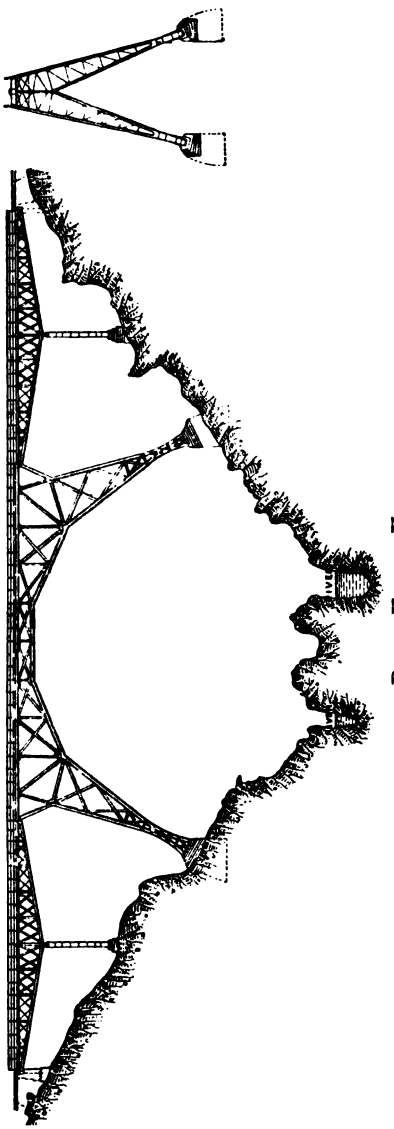


Fig. 49. BLAAU KRANTZ VIADUCT.

Sir Alexander Binnie.

Sir ALEXANDER BINNIE wished to add to the words of the President his personal thanks to the Author for having brought forward a subject which did not usually occupy the members of the Institution. The Paper was useful, because the Author drew attention to some of the fundamental points necessary in any structure designed with æsthetic effect. One of the first alluded to was that a structure should follow, as far as possible, the beautiful lines which Nature laid down for guidance. Looking back to the man whom he might call the father of the engineering profession—Smeaton—there was an instance of the adaptation of those lines of Nature in the construction of the Eddystone Lighthouse, a structure which had always claimed admiration for the elegance of its proportions. In bridge-building pure and simple there were the works of Rennie, Telford, and

Stephenson, which had been referred to with remarks of the strongest approbation. The bridges which Rennie had built across the Thames would ever remain monuments, not only of engineering, but of beauty. They had formed throughout the world models on which other bridges had been constructed. But he wished in that respect to draw attention to bridges constructed by Telford and by Stephenson. There was a general consensus of opinion that the Menai Bridge and the Britannia Bridge were objects not only of engineering skill, but of beauty and of grandeur. The same engineers had had to deal with a somewhat similar problem at Conway, and it had been remarked that their efforts had not been crowned with the success which had attended their labours at the Menai Straits. That pointed at once to a very important matter with regard to the construction of any bridge, when regarded from the æsthetic point of view, namely, that the site of the structure had a great deal to do with its appearance when finished. The bridges which crossed the Seine could not be compared with the bridges which crossed the Thames, without taking into account the fact that the one river flowed between comparatively steep banks, and the other for the most part was bounded on one side by high land and on the other by marsh-land. The difficulty introduced into the site of a bridge must of necessity govern the appearance of the structure when it was completed. Beyond the mere question and accident of site, the engineer often had to deal with other conflicting elements in the production of his design. He often appeared before Parliamentary Committees, where several opposing interests ultimately decided the width of his piers, the headway to be given to the bridge, and the gradients over it; so that, without his consent, and often against his advice, he found himself in the position of having to elaborate out of the main features of his structure something which would be most pleasing to the beholder. But, on the whole, he thought engineers had not altogether failed in their endeavours to carry out their work with the approbation of the public. The Author spoke of the construction of bridges of different materials, and said that attempts might be made to present in disguise one material for another, or possibly the resulting effect might be marred by the employment of too great a variety of materials. The use of one material to represent some other material was the subject to which he wished to draw attention. He would ask the members to look back at the history of classic architecture, to trace the source of the column, the source of the cornice, and the meaning of the triangular pediment at the top of

Sir Alexander Binnie.

Sir Alexander Binnie.

a classic design. Was that not in itself but the reproduction in stone of the pre-historic wooden building in which the ancestors of the Greeks lived? Turning to a more striking instance of a fact, patent to all who had travelled in the East, and forcibly brought to public attention by Fergusson in his work on ornamental art—namely, that the actual structures in stone at the present day, amongst the most beautiful the world had ever seen, were exactly copied from wooden models—he had himself seen within the same city a building in wood, and at no great distance from it a building in stone, which was almost a reproduction in every detail of the wooden building. It was absurd to say that the effects of one material must not be represented in another. To lay down a canon of art such as that was to destroy the possibility of art in any future structure. The present was a period of transition, not between a wooden and a stone epoch, but between a stone and an iron epoch. It must have taken a long time for the old architects to evolve those beautiful stone designs out of their wooden model. When it was said that the iron structures of to-day were not æsthetic, because engineers had not cultivated that taste which was necessary to appreciate the beauty of the designs, conclusions were being drawn too hastily. When the public became educated up to appreciation of the meaning of the structures; when they saw with what skill the various forces were balanced and counter-balanced, and how the molecular forces of expansion and contraction were provided for; then perhaps it would be time to say whether bridges were ugly, hideous, and not æsthetic. In the process of development the elements of beauty would gradually creep in, partly by concessions from the crude designs of the present day, and partly by that understanding of the labours of the builders which must spring ultimately from the true appreciation of means to end. But, after all, was it not a matter of personal opinion? What one man or woman considered beautiful, another man or woman did not. Nothing he had experienced brought so vividly before his mind the fact that art was a personal thing, a certain feeling that existed in the artist, as contemplation of the great works of painters and of sculptors. How would Michael Angelo have acted under the directions of a "committee of art"? He himself had attended committees of art, and the difficulty which he had always felt was to get such a committee to come to any concrete conclusion. The gentlemen composing the committee, for whom he had the greatest respect, had their own ideas, which differed from one another, and it was difficult

to focus them. Engineers were not so devoid of the artistic faculty as was supposed. They were met by difficulties of site and difficulties imposed by conflicting authorities; but he thought they could show a fair record in the works which had been constructed, and he looked forward with a considerable amount of hope to see in the future modern structures evolving into the most beautiful objects. He believed that designs would be produced as beautiful as were the stone copies which succeeded wooden structures. Sir Alexander Binnie.

Mr. R. M. PARKINSON remarked that according to the Author simplicity of design was an eminently pleasing quality. The question was, who was to be pleased? He did not think bridges should be designed to please the eye of the engineer or the highly-trained eye of the architect or artist. The beauty of the arches in the side aisles of St. Peter's at Rome was due to the very deeply-cut reliefs in the spandrels, and if those arches had been simpler he did not think the public would have appreciated them. The artist and the architect very much preferred the cathedral in Florence to that in Venice, but he thought the public generally would prefer the more highly wrought architecture of Venice. Therefore, something more than simplicity was required. The thing to be considered was, what were really the elements from which beauty could be obtained in a bridge? In an arched bridge the question arose as to the right curve to adopt. He thought the circle was generally considered to be the ugliest curve, although it was scientific. The circle practically agreed with the line of thrust. But he believed architects laid down the rule that a compound curve was necessary to beauty—not a curve changing suddenly from a sharp to an easy one, but something like the parabola. The only case in which there should be a sudden change was in the reverse curve. In the cut-water of a bridge the usual curve was a pointed arch, but he believed it would be much better in cut-waters to have a reverse curve, so as to show the angle of the pier. The Author stated that in an elliptical bridge the higher the rise the better, because it had a stronger appearance. He thought the public generally would appreciate Westminster Bridge more than Waterloo Bridge, as the sharper curve produced a more pleasing effect to the eye, although probably it was not so scientific. The Author also appeared to think that it was difficult to get due effect from iron and stone. He had always thought that the way to secure proper effect was to have considerable contrast. For instance, in an arched bridge a Mr. Parkinson.

Mr. Parkinson. pointed arch was better than an elliptical arch; and he thought the Skeldergate Bridge at York had a much finer appearance than Westminster Bridge. The contrast between the iron and the stone was also very pleasing in both. The Author did not refer to the question of painting, but a great deal of effect could be obtained from a coat of paint. In a bridge such as was illustrated in *Figs. 13* and *14*, the pilasters had been found fault with, and he thought they might with advantage be replaced by sinkings in the spandrel. It had been said that the bane of English architecture was the 4½-inch jambs; to get beauty it was necessary to have a deep jamb. In some viaducts he had seen, the parapet was very disappointing, because the cornice did not stand out enough. He had heard the objection raised against St. Peter's Cathedral that the proportions were so exquisite that the effect of its size was lost; but he thought in a bridge the cornice ought to look uniform with the rest of the work, and not be made small, in order to give an idea of height to the viaduct. Nothing had been said as to the widths and heights of pilasters, but the question of the proper proportions to use was a matter which sometimes troubled engineers. He believed that if anything was not square it should be decidedly oblong, not slightly wider than it was high. If pilasters were used slightly higher than they were wide, they had a very ugly appearance, but if the height was increased considerably the appearance was improved. With regard to the education of the engineer, he thought one of the most beautiful buildings was Giotto's Tower in Florence, which was the only work of the artist. He did not know how he could have arrived at such a climax without any previous experience.

Mr. East. Mr. ALFRED EAST remarked that, not being an engineer, he would not have spoken had not it been for some remarks that had fallen from Sir Alexander Binnie, which had given him information concerning the art he followed which he had not possessed before. Sir Alexander Binnie had remarked that art was a matter of opinion. He might say the tensile strength of iron was a matter of opinion; but it was not. He might also say, in reference to the æsthetic treatment of bridges, that it was a brave thing for any member of the Institution to bring forward such a Paper, and he took it that the Author saw the dire necessity for doing so before venturing to place the Paper before such an assembly; for he knew that engineers were, in the first place, of necessity utilitarians. The primary importance of a bridge was that it should serve its purpose. But if any decoration, ornament, grace

of line, or beauty of structure could be added to the bridge without destroying its useful purpose, surely that was worthy of consideration. Bridges were permanent structures: they were not like hoardings, to be taken away when their temporary purpose was served. Engineers were responsible to a certain extent for the cultivation of public taste, and when he looked at the designs on the wall he did not think that fact entered into their consideration. He noticed in them many opportunities for improvement. The spacings of the girders were optical irritations, and offended the eye terribly. He considered the sentiment of strength in the structure of a bridge was necessary, the feeling that it served its purpose, the feeling that it was strong, as well as the actual fact of its being so. When he was in the country painting a landscape, and he saw an ugly bridge, he thought out the problem of its situation. Perhaps he might come to an erroneous conclusion, but very frequently he thought that, with a little more consideration, the designer might have made the bridge a pleasing object in the landscape. He was ashamed of the bridges of his native country, as a rule. He had, however, seen splendid bridges and fine viaducts. Quite recently in Spain he had seen a magnificent aqueduct built by the Moors, a thing of grace and beauty: it was fine as a piece of architecture, and it served its purpose. He could not refrain from speaking on the Paper, because he considered that the rules of art were as necessary—and not a matter of opinion, as had been suggested—as those of science. Behind all great art, there was a dignity and simplicity, a quality which had to serve its purpose as much as the quality that made fine construction serve its purpose. Mr. East.

Mr. CHARLES HAWKSLEY, Vice-President, observed that a great many of what, he was afraid, must be called the ugly structures depicted in the diagrams, arose perhaps not only from the necessities of each case, but from want of a better training in architectural principles than engineers generally had. Again, he thought it might be due also to not devoting sufficient time and attention to study of the appearance as well as the utility of the works designed by engineers. Then there was the client, who generally had an idea, in which the engineer perhaps sometimes participated, that if a thing was only ugly it must be economical. He hoped the day would come when either by better knowledge and more study, or with the aid of their architectural friends, engineers would be able to improve such things. Sometimes, perhaps, there was another element, but, he thought, for the credit of the profession it should not have any great weight—namely, Mr. Hawksley.

Mr. Hawksley. that it was much cheaper in the drawing-office to design an ugly structure than it was to design one that looked well. When he had the opportunity he always endeavoured to impress the views he had enunciated on students, who were the rising generation of engineers.

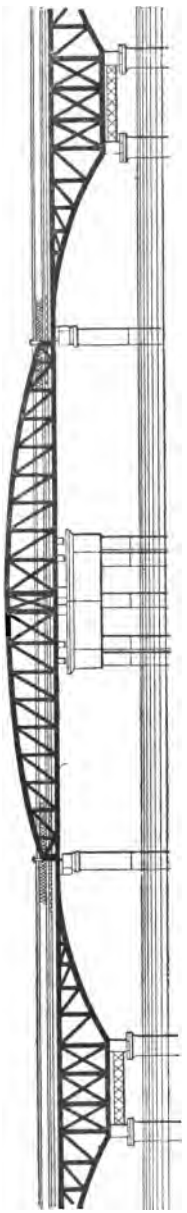


Fig. 50.

Sir Frederick Bramwell.

Sir FREDERICK BRAMWELL, Bart., Past-President, wished to repeat an anecdote told him by the late Mr. Thomas Hawksley, Past-President, which was appropriate to what his son had just said with regard to considering clients in reference to ornament. Mr. Thomas Hawksley bad told him that, once when he was making one of his many hundred waterworks for a corporation, the plans included an arch with a keystone which he had caused to be vermiculated. One of the Town Council, a tailor by trade, complained of the extra cost of the work, and Mr. Hawksley, in walking behind the tailor, saw that he had two buttons at the back of his coat. It appeared that those buttons were used originally for a horseman to button up the flaps of his coat when on horseback. The horseman disappeared and went by train, but the tailor still placed two buttons at the back of his coat. That gave a chance to Mr. Hawksley, and he said, "You complain of my extravagance in the vermiculation of that keystone: will you tell me how you can justify those two buttons at the back of your coat?" The tailor could not justify them, and, as always, Mr. Hawksley had the better of the argument.

Mr. Goodwin.

Mr. G. A. GOODWIN referred to a diagram (*Fig. 50*) of a bridge he had designed some years ago, composed of a swing span with two cantilevers on one side and three on the other. His object in bringing it forward was to show one method of what he considered æsthetic treatment of a bridge with a swing span combined with fixed adjacent spans. It would be seen that the curve of the upper boom of the

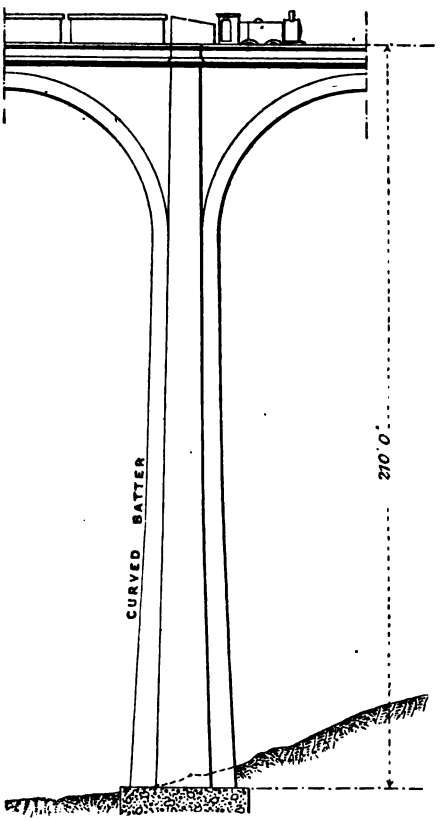
swing span conformed with the curves of the lower booms of the side spans, and gave a somewhat pleasing effect. At the same time the design was very economical; in fact it had been too economical in that particular case, as the metal of the centre portions of the spans had worked out so thin that he had had to increase the sections to allow for wastage. The highest part of the span was next to the shore, which allowed small boats to come alongside the wharf. In a larger bridge he thought the design could still be used by allowing the centre portion of the spans to be somewhat on the lines of Fig. 35, Plate 3. After what had been said in the discussion, he thought it was not always true that "a thing of beauty was a joy for ever;" and as men were frequently of different opinions, he had no doubt some members might consider that the particular detail of the bridge referred to had not a pleasing effect; but that only showed the impossibility of satisfying everybody. Bridges in public thoroughfares ought to be made as æsthetic as possible, but he did not think engineers would get much sympathy from railway companies in that matter, railway bridges in towns being usually covered with advertisements. He thought it was a disgraceful thing that in towns like Manchester and Glasgow, and in other large towns which were very great delinquents in that respect, such a thing should be allowed. Mr. Goodwin.

Sir GUILFORD MOLESWORTH confirmed Mr. Hawksley's remarks from his own experience. When a young man he had wanted to put some inexpensive æsthetic embellishment on the central arch of a viaduct, which he thought would be very appropriate. His chief engineer said to him: "My dear fellow, whenever you have to choose between an ugly thing and a beautiful thing, choose the ugly one, because the directors will like it best." Sir Guilford Molesworth.

Mr. R. J. G. READ remarked that the Paper dealt with a subject which was to a large extent a matter of opinion, and therefore it was not surprising that so many different views had been taken of the question. With regard to high viaducts, to his mind they were a very pleasing feature in a landscape, and could be made to carry out the æsthetic views of any architect. Mr. Elliott Cooper had referred to the high piers shown in Figs. 8–10, Plate 2, and had rather objected to Fig. 9, which the Author considered to be the best. For his part he was disposed to agree with the Author, and he had placed on the wall a diagram (*Fig. 51*) of one of the piers of the viaduct of the Grueize, in the South of France, which had been built on a railway passing over a deep gorge. The Mr. Read.

Mr. Read. viaduct was built of limestone, and from the description of it, he gathered that it was one of the most beautiful viaducts in France. The train went over it at a height approaching that of the top of the piers of the Britannia Bridge. The piers were slightly curved, the pilaster was carried up to the parapet, and the arch sprang from the curve of the pier. He thought it was a very graceful example of a viaduct of that kind. Foreigners, especially the French, had devoted a great deal more attention to, and had succeeded more admirably in giving a pleasing effect to their structures than English engineers. He had laid on the table a photograph of a viaduct he had seen some time ago in France, which illustrated the abutment-piers mentioned by the Author. They occurred at every third pier, and had a very pleasing effect. In stone the ancients had had a natural material which could be only used in compression. It was easy to build an arch or structure with stone in compression, because an enormous weight could be imposed on a stone arch without breaking it; but it was very difficult to go to the other extreme and to reduce the stonework to the least possible amount; and yet that was the difference between ancient structures and those of the highest class now built. Engineers now were supposed to know more about the lines of action of the forces in a structure of any particular form, and to place the material in the best position for resisting the

Fig. 51.



PIER OF THE GRUEIZE VIADUCT.

stresses which came upon it. He did not think the present engineering structures could be compared with those of olden times. As Sir Alexander Binnie had observed, the present was a period of transition, and perfection had not yet been attained. The subject which had been the main influence in shaping engineering work, namely, the great discoveries of science, had not yet been alluded to. In the seventeenth century, by the aid of the mathematicians, science made great strides; important discoveries were made in the treatment of mathematical problems; and problems were solved which had hitherto remained insoluble. It was interesting to note that in the solution of mathematical problems at the time of Descartes, Leibnitz, Newton, and others, in the seventeenth century, great importance was attached to a solution which was done in a graceful manner. Some men solved problems in a roundabout and cumbrous manner; but they were not reckoned equal to those who solved them in an elegant manner. Those men were the precursors of the modern engineer, who had benefited by their discoveries and inventions. The steel structures of the present day were the outcome of improved scientific knowledge and improved mechanical methods of manipulation of material. The material now available could be used in tension, and consequently demanded different treatment from the old material. He thought structures like large bridges and viaducts of the lattice-work type were the most advanced forms of bridge structure, and that in that form lay the right direction for progress and perfection in the future. With regard to the Alexander III. Bridge in Paris, it had been built principally with a view to artistic effect; but it was curious to note that although that particular work was thought to be the most recent of its kind, the features of the pilasters on the abutments very much resembled those of an old Roman bridge built at St. Chamas, in France, which had a triumphal arch at each end. With regard to the Viaur Viaduct, he had seen a model of it in Paris, and he thought it was one of the most advanced types of construction. It was not altogether an arch, but an arch with a weight at its back tending to lever it open; and as the piers were not fixed but hinged, if the back part were not properly proportioned and overbalanced the centre, the whole bridge would go over. The plans and calculations for that structure necessitated a very high degree of scientific as well as engineering knowledge. Mr. Read.

Mr. Henry Davey complimented the Author on having brought such an interesting Paper before the Institution, and thus re- Mr. Davey.

Mr. Davey. lieved for a while the dulness of purely utilitarian ideas. He did not gather from the Paper that the Author laid down any laws to guide judgment as to what might be considered æsthetic and what the reverse. There were laws of artistic feeling—laws which were very difficult to define, but which were derived from a true appreciation of Nature, the source of all artistic feeling. Those laws existed in proportion and grace of outline, amongst various things. Proportion and grace of outline naturally had to be regarded in connection with magnitude and environment. It was obviously absurd to treat a structure of such magnitude as the Forth Bridge on lines which would be quite consistent in structures of more moderate dimensions. Again, with regard to environment, a model of the pyramids of Egypt, for instance, would look rather out of place in the grounds of the Crystal Palace. All those questions naturally set aside any attempt to formulate laws to apply in all circumstances. There was, however, a law implied in the argument of the Paper, one which he did not quite agree with and which he thought contained a fallacy, viz., the implied law that, to be æsthetic, a bridge should exhibit to the eye the distribution of stress within the structure; in other words, that nothing should be hidden. Following out that idea, the Author had condemned very strongly the outlines shown in Figs. 23 and 24, Plate 2; he might have condemned them because they were ugly structures in themselves, but he really did so because a centre girder between two cantilevers had been incorporated in the general lines of the structure, and that condemnation was due to a false sentiment. It seemed to Mr. Davey that if the bottom member of the cantilever was curved to coincide with the outline of the centre girder, that girder might be incorporated with the bridge without its usual obtrusiveness. How that might be carried into effect would readily suggest itself to any designer of bridges, and it appeared quite a simple matter to incorporate a centre girder so that it fell in with the general lines of the structure, and in that way to get a more artistic effect. The argument that nothing was to be hidden was entirely wrong. A tree was not less graceful because its roots were out of sight; a picture might be no less artistic because it was not realistic; and it did not require the eye of an anatomist to see the beauty of the human hand. Therefore, relying on the general principles of Art instilled into the mind by observing Nature, it would be seen that Nature did hide, and by so doing did not destroy the artistic effect. To carry the argument a little further, the Tower Bridge might be criticised for containing architectural work which did

not form part of the structure. That was false sentiment. He would go so far as to say that, even in a cantilever bridge where the supports of the cantilever, owing to the nature of the material, in structures of moderate dimensions—he was not speaking of huge structures where grace of outline and majesty of conception were the principal sentiments, but of such structures, for instance, as crossed the Thames, or of structures surrounded by buildings —it would not be at all out of the way to cover the supports of the cantilever. If a cantilever was designed with small details of trellis-work, it was obvious that any architectural treatment of the stonework it might be more ornate than it would be if the cantilever was more open work. There was an old verse:— Mr. Davey.

> Straight is the line of duty,
> Curved is the line of beauty;
> Follow the first, and thou shalt see
> The second ever follow thee.

It was true that a curve was a line of beauty, but it did not follow that associations of curves would be always beautiful, and in dealing with reverse curves very careful treatment was required. The designer of the Borcea Viaduct (Fig. 26, Plate 2) had introduced reverse curves in as ugly a way as it was possible to do so. Reverse curves were constantly seen in the finest architectural work, especially in the Houses of Parliament. To be beautiful a curve must be a free-flowing curve, and the arch was almost the most beautiful thing in architecture. It was impossible to walk through a wood and observe the crossing and bending of the branches of the trees without discovering arches of all kinds, the elliptical arch, the semi-circular arch, the Gothic arch, and every form of free-flowing curve. It did not appear inconsistent to construct a bridge on a compound principle or on a simple principle appearing to be a compound principle—the appearance only being put in for artistic effect; *e.g.*, when an arch was put in for the lower or upper member, not because it was necessary for constructive work, but because it was desirable for æsthetic effect. In support of his argument he drew attention to the Britannia Bridge, in which it was difficult to say whether the girder was divided or continuous. In that instance there was concealment with artistic effect. In Fig. 40, Plate 3, there was no appearance whatever of hollowness in the supporting piers, but the Author said they were hollow and therefore the more to be appreciated. That was wrong. It was only necessary to look at a thing to see whether it was beautiful or

Mr. Davey. not. Poetry might be said to be, "Thought, often thought before, but ne'er so well expressed:" the artistic feeling in construction had the subtlety of poetry—the difficulty was in the expression.

Mr. Blashill. Mr. T. BLASHILL remarked that by far the greater number of specimens of bridge construction placed before the meeting by the Author had to do with the use of iron, and such structures were essentially the work of engineers and not of architects. His view of the matter was that, in the construction of a bridge to which artistic qualities were to be given, he would depend largely, in fact almost entirely, upon the engineer for the outline. He could not think that some of the bridges illustrated, which appeared so ugly, had been designed in a manner that modern engineers would imitate. There was an absence of that grace of outline which usually characterized the best of modern iron constructions. It was only necessary to look at the Forth Bridge from below to admire its general outline and composition. He did not speak as an engineer, but knowing something of the manner in which it had been constructed, and appreciating very highly the skill of its constructors, he admired the appearance, the solidity, and the general character of the bridge, and its adaptability to its purpose. That was enough in a thing of that kind. There were bridges, however, which had to be built in places where the public expected beauty. He had been concerned in cases of that kind, and he had always desired to see first of all what the engineer wished, what it was that would best carry the load; and upon that he had endeavoured to work with him—not to introduce things which would interfere with the engineer's work, or overload it with ornament or architectural details, but as simply as possible to emphasize or give character in the smallest possible parts to the design. He considered that an engineer's work overloaded with architectural ornament was likely to be more or less open to criticism. Perhaps engineers thought less of the beautiful in design than they might do, and in that some engineers were wrong. They might well go to the same sources as the architect to get precedents, and to perfect themselves in the art of beautiful construction, and they would be very successful if they did so. Then the bridge might be the design of one person instead of two. With regard to the Britannia and Menai Bridges, he did not know that in respect of beauty the architect could improve them very much. In the question of the construction of a bridge, the engineer should be asked first of all to say precisely what he wanted, and Mr. Blashill would have great confidence that the engineer's outline would be graceful

and lend itself to the little architectural decoration that might be called for, or, artistically, would be permissible. Mr. Blashill.

Mr. W. E. RILEY thought it was very difficult, in co-ordinating two professions like engineering and architecture, to avoid being dogmatical. Each trenched upon its neighbour's domain, and it was necessary to consider with a good deal of sympathy where one left off and the other began. Engineers in the past had dealt with the problem of bridge-building in a very able way, but he ventured to think not enough emphasis had been given to the question as to where a stone structure should be designed and where the structure should be a purely metal one. He did not think there was an architect in London who would be ashamed to have been the builder of either London Bridge or Waterloo Bridge, and those bridges had been built entirely by engineers. He might touch first on what he conceived to be the proper characteristics of a stone bridge, and ask the members to look at it first from the water-side. There was the pier with a cut-water, the arch, the screen, the cornice, and the parapet, and those he thought should be dealt with in a very simple manner. The cut-water in very early bridges, as in the Bridge of Trajan, was carried practically to the top of the parapet. In the early bridges across the Arno there was the same treatment, and it would be found in the beautiful bridge at Bideford. That was a little detail mediæval architects probably employed to direct the masters of craft passing down the river into their proper channel, in order to make the opening between the piers. The beauty of London Bridge and Waterloo Bridge appeared to him to be the great strength which was evinced in the treatment of the arch, and the great simplicity with which the screen, the cornice, and the parapet had been made to harmonise one with the other. The proper and legitimate points for monumental architecture on a bridge were the approaches, not on the screen of the bridge at all. He thought that idea was exemplified in the Alexander III. Bridge, which he considered to have been the finest piece of construction at the Paris Exhibition. Saltash Bridge, looked at from the Saltash side, had a very imposing appearance. It had been criticised on account of the tallness of the piers; but the piers were sufficient, the construction was fine, and considering Brunel's precedents when he had designed the bridge, Mr. Riley thought he had made a fine engineering and architectural success. He could not quite understand why a metal bridge should be expected to do anything, æsthetically, but convey an impression of its fitness for its work. The mere size of a Mr. Riley.

Mr. Riley. bridge and the feeling of its security appeared to him to be quite sufficient. Anything in the way of ornament on a bridge like the Forth Bridge would be meretricious. The conception and successful carrying out of a fine engineering scheme appeared to him to be an ample reward to those who had been engaged upon it. With regard to the swing-bridge referred to by Mr. Goodwin (*Fig. 50*), it had been generally agreed that it was a pleasing structure, and, viewing it in the manner in which it was shown in the diagram, he concurred in that opinion; but he would ask the members for a moment to conceive that the swing portion of the bridge was open, when it would be seen that there was no necessity whatever for anything in the way of arch treatment in the wings on either side. He thought it would have been legitimate treatment to make those girders flat. The curved lower boom was unnecessary, and it seemed to him that when the bridge was open it would give an impression of weakness. The bridge across the East River at New York had been severely criticised, mainly because the piers were conceived in a somewhat shoddy Gothic style. It would have been a great deal better, he thought, to treat them in a simple, massive manner, without attempting too much "architectural" ornament; but he knew no modern engineering or architectural work which had given him such a thrill of pleasure as that bridge had given him the first time he had seen it. He thought that to endeavour to co-ordinate too closely the two professions of engineering and architecture was somewhat a mistake. In the Renaissance period engineers and painters had been practically the same people; Michael Angelo had done some fine engineering work as well as fine painting and sculpture. Frankly, he would never attempt to ornament a purely statical structure. Its size, and the feeling that it was fully justifying its position by doing the work it was called upon to do in bearing loads crossing a ravine or a river, was ample justification of its simplicity and lack of so-called ornament.

Prof. Pite. Professor B. PITE, as an architect, rose with great pleasure to take part in the discussion, feeling strongly that the design of bridges was a source of very considerable artistic emotional pleasure to the architect who ventured to practise it. The emotions that would follow in the construction of the bridge were another matter, and it was on that point that co-ordination between the two professions would be necessary for any peace of mind to either the one or the other. The title of the Paper evidently suggested an entirely different chain of ideas. The æsthetic treatment of bridges had appeared to suggest to Mr.

Davey a delightful reference to Nature, Nature which under no circumstances knew a straight line, a right angle, or a segment of a curve, without one or other of which all architectural accomplishment was impossible. He admitted a very strong sympathy for his fellow creatures who felt that the study of Nature was the basis of all Art; indeed he was sure it was. All were, as creatures of Nature, bound to study it, and their environment in it; but he humbly suggested that a very real appreciation of the laws of Nature lay at the bottom of all sound and effective architectural or engineering design, in directness, simplicity, and avoidance of affectation. There were a number of illustrations that could be drawn from the freaks of Nature, the freedom of Nature, the picturesqueness of Nature, the manner in which Nature set its own laws and principles at defiance, the way in which Nature decorated apart from construction—the stripes on the tiger's back being an excellent illustration of the latter; but he was afraid that in a discussion of that character it would not be possible, without a very long disquisition and possibly a great deal of difference of opinion, to derive any helpful considerations from reference to Nature herself, until a few fundamental definitions had been settled. It might be necessary to define what was æsthetic; it was certainly necessary to define what was artistic; and he would assure the members it was quite impossible that evening to define what was ugly. If it was agreed to banish those terms with any reference to Nature, he thought it might be possible to do a little useful work in the discussion. He might urge upon engineers that to a lay mind there was a beauty in a beautiful machine, as such, and he did not know why a different meaning should be attached to the word beauty apart from beauty of workmanship, of fitness, of power, and of directness of expression, beauties which were recognised now in the most unaffected locomotive, and which were beginning to be recognised in the most hideous ironclad, which expressed its fierceness, its strength, and its purpose in the very want of æsthetic quality in its lines. Why should it be necessary, when talking about a beautiful structure of metal, a structure of a mechanical nature to serve a mechanical purpose, to at once charge the mind with definitions of beauty, striving to ally it to Nature, to Hogarth's curved lines of form, and—as apparently some members of the engineering profession were anxious to do —to architectural forms which were themselves subjects of much discussion and conflict of opinion among architects? He would like earnestly and heartily, as a practical designer, to press Prof. Pite.

Prof. Pite. home the fact that artistic simplicity would be achieved by dissociating from the mind all architectural phraseology, all architectural ornament, all architectural traditions, such fantasies as the curve and compound-curve lines of beauty, and by aiming in metal bridge building at exactly the same beauty of workmanship, beauty of economy of material, beauty of accomplishment that pleased the mind in any form of mechanical effort. In that way engineers would keep clear of the changing whims of artistic fashion; keep clear, in metal, of the traditions of an architectural art of stone; of the conditions of an architectural art in wood; and would work out in iron, with its different qualities and stresses, an æsthetic style based on the absolute scientific necessities of engineering practice, which would without doubt afford infinite satisfaction to generations to come. As an illustration he might draw the attention of the members to the recognised beauties of Gothic architecture such as was seen in Westminster Abbey. Those beauties had been achieved without any affected reference to Nature, or to imported forms of Art in detail, decoration, and ornament. Gothic architecture in its evolution and development was based upon the engineering necessities of vaulted construction applied to the plan of a church, transeptal, apsidal, or the compound apse, such as was found in Westminster Abbey. It might safely be called a sanctified form of engineering; it was engineering in stone, allying with itself and to itself in its progress highly developed craftmanship such as was found in stone-carving, wood-carving, glazing, and metal-work. Following the same principle in the new age, with the new materials, would lead assuredly to results equally successful. With regard to the unhappy mixture of architecture and engineering which frequently took place in bridge designs, he would like to point out as an architect who had to practise the mere outlines of mouldings, to study their nature and their effect, that there was a whole science and a whole art in moulding. There was also a whole science and art in the development and application of ornament. Ornament that was meaningless, that was achieved rapidly, ornament that was not the carefully expressed utterance of the delight the designer felt in the work of his own fingers, a delight which he succeeded in imparting by sympathy to others, was not ornament worth having. When it came to the application of recognised architectural forms such as architectural orders, cornices, rustications, treatment of voussoirs, he would have it remembered that behind each of those things there was a highly interesting and complicated history, and that the reckless

application of traditional forms to highly modern structures would be only productive before very long of possibly an acceptance of the skill with which the engineering difficulties of a particular case had been overcome, but with a contempt for the embryonic architecture which had applied unstudied detail to an engineering work. Such work, he was afraid, was inevitable. It was that result which made the subject of the co-operation of an architect with an engineer in bridge construction necessary. He ventured to urge that any attempt to assimilate architectural surroundings to bridge design was wholly mistaken. A successful artistic result came more by contrast than by affinity. The application, for instance, of a castellated form to a bridge pier or a bridge abutment was an anachronism which rankled the soul of an artist to its very core, and he earnestly begged engineers to consider that castellated architecture had feelings of its own. It had a past which ought to be respected, and traditions which ought not to be outraged for the sake of satisfying an untutored craving for ornament. The same thing underlay every detail. In stone bridge-architecture exactly the same laws would produce satisfactory æsthetic results as would produce it in iron bridge-architecture. The simple expression of the most useful, the most suitable, the most economical arch, and, if the pier was in the waterway of a stream, the most powerful and economical form of pier and abutment, and the simplest form of parapet, would bring success. He had taken the most recent design published of the new Vauxhall Bridge, and had accepted its engineering statements with pleasure. With the aid of a sheet of tracing-paper he had outlined every factor which represented an engineering truth. He had taken the simple outline of the parapet, the outline of the arch, showing no architectural detail, no cornice which affected proportion, no pier which indicated the designer's idea of traditional forms of architectural beauty, and no ornament which might be shown in a temporary and preliminary manner—the outline and the form of the bridge expressing solely its purpose, solely the object of stretching from shore to shore with elegance and power; and the bridge had in those factors, apart from architectural trimmings, every possible æsthetic element of success. It was when the architecture was added, when the science and art of moulding, the proper expression of cornice detail and balustrade, were attempted, that it was found, in a bridge of that scale, that the ordinarily accepted traditions derived originally from a Greek temple, copied by the Romans, and in the Victorian age found in every street, became out of place; and

Prof. Pite.

Prof. Pite. that there was no living traditional architectural form which could be applied without thought to the current necessities of building. The science, the art, the history of architecture, alike appealed for the most careful, complete, and æsthetic consideration of the artistic details of the bridge. Whether engineers, with the manifold claims on their skill, their science, and their time, felt themselves at liberty to enjoy and do honour to the whole art of architecture hidden in moulding, column, or parapet, was for engineers to say, and not for him; but he hoped the public in the future would justify their decision.

Sir Benjamin Baker. Sir BENJAMIN BAKER, K.C.M.G., Past-President, apologised as an engineer for occuping a few minutes, because he considered the discussion to be an architect's discussion. He did not suppose engineers wished to hear the opinions of their professional brethren on the subject; they really wanted to hear what their other brethren, in a certain sense, the architects, had to say. He thought if there had been nothing else but the remarks of the President of the Royal Institute of British Architects and those of the learned professor who had just spoken, the reading of the paper would have been amply justified. He did not think a word had been said by either of those gentlemen which he did not cordially agree with, especially the absolutely sound common sense which had been so well put forward by Professor Pite, and which he hoped would sink deeply into the mind of every bridge-engineer present. Architects and engineers were agreed that the fundamental principle was fitness for the purpose, but by agreeing on that principle the difficulties were not overcome. That had been well illustrated in the discussion, and Mr. Blashill had reminded him of it by a reference to the Britannia Bridge. A Fellow of the Royal Institute of British Architects had expressed surprise that the Britannia Bridge had not been illustrated in greater detail as an example of what things should be, and that opinion had been endorsed by at least one engineer. He was afraid in that instance both architects and engineers had violated the fundamental principle laid down, viz., fitness. When he had first seen the Britannia Bridge many years ago, he had been unable to make out the piers. Knowing it to be a tubular girder bridge, he could not understand the object of extending the piers high up above the tube. Looking at it longitudinally, he could not see the use of the perforations in the line of the bridge through the piers; and he had come to the conclusion that it was a girder bridge with suspension-bridge piers, which was a very curious thing. He had ceased to admire the bridge from that time. But as both architects and engineers in

Sir Benjamin Baker.

the discussion had selected that bridge as an illustration of what was to be aimed at, he had had the question looked up, and he had found the explanation in a report by Robert Stephenson, the engineer, to the directors of the Chester and Holyhead Railway in 1846. The explanation was to this effect: "Mr. Hodgkinson thinks suspension chains would be a necessary or useful auxiliary; Mr. Fairbairn says the tubes will stand alone: this will not make any difference to the masonry, because I am building the piers to admit of chains." He had heard a great deal of abuse of castellation and of mediæval contrivances for pouring down molten lead on the heads of enemies; but here he found architects and engineers holding up as a model a bridge designed for suspension chains which had never been erected! He only brought that forward as an illustration of the difficulty of applying the principle agreed upon, viz., that fitness was the fundamental condition of beauty. Then it was necessary to take instruction as to what was fitness. He had not the slightest doubt that the man who designed the windmill never had an idea beyond using the material he had at hand in the best way that his mechanical knowledge enabled him to do. Then, when he had done it in a straightforward way, all the leading painters of the day came and selected it to put in their landscapes as a picturesque object. But he was certain that if the builder of that windmill had come to him or to Mr. Davey, they would have puzzled their brains how to make a pretty windmill—and all the painters would have avoided it. There was nothing like honesty—going straight at the object in view. Then, in time, when people were sufficiently educated, if the work had been really done honestly, economically, and straightforwardly, with the materials of the district, the result need not be feared. It was not necessary to labour the question of the collaboration of architects and engineers. An engineer was really such a broad-minded man that any question of jealousy or false pride could not enter into the matter. Engineers consulted each other; on an electrical question they went to one man; on a question of locomotives to another; on a question of waterworks to another; and the idea of any jealousy or false pride in consulting architects was outside the question. As an instance he might mention the case of the great dam in Egypt. When the contract drawings had been prepared they had been handed over to the architectural department, and it could be easily imagined what had happened. When they had come back they had been saturated with Egyptian temples, and when he had seen the contract drawings lithographed, he had told

Sir Benjamin Baker.

the contractors not to take any notice whatever of architectural detail, because the dam was not to be an imitation of a temple 4,000 years or 6,000 years old. Of course all that detail had been struck out. Then the tourists of all professions, artists, architects, and engineers, had been thoroughly dosed with Egyptian temples, and they all arrived at Assouan with ideas as to how the great dam ought to be finished. He had told the contractors to get their ideas and put up full-sized models on some of the completed parts of the dam, and make the suggestors ashamed of themselves. That had been done, and it had frightened Lord Cromer exceedingly. His Lordship had come down and seen about ten different sections of cornice along the finished part of the dam, and when he had met Sir Benjamin in Cairo, he had looked at him very seriously and had said: "I will find you any amount of money you like to make the dam safe and suitable, but I am not going to waste £150,000 or £200,000 putting up architectural details." He had told Lord Cromer there was no intention on his part of putting up anything of the kind; he had simply put up the models to see how they would look under actual conditions, in strong sunlight with very deep shadows. In the result, everybody had agreed that a suggestion which looked all right on paper for a limited length, when applied to the two sides of the dam, giving 2½ miles of cornice, was simply a thing to stamp the man who put it there as a madman. That was another instance of the fallacy of jumping to the conclusion that all the difficulties were solved in arriving at the principle that architects and engineers should collaborate. When very young he had thought he could do without architects; now he always consulted them. He might convince the architect, or the architect might convince him; but in any case the questions were argued out, and there was agreement in the end. It was impossible to say, "Here is an engineering drawing; pass it on to the architect to be altered and made architectural." When it came back to the engineer, he might say that it falsified the whole principle of the work, and did not meet his requirements. Ultimately, however, some agreement might be come to. In the collaboration of engineers and architects, there would have to be a constant see-saw of the plans backwards and forwards. As he had said, when very young—only twenty-two in fact—he had thought he could do without architects, and he had designed and carried out some very pretty work indeed. It had been so pretty that it had attracted the attention of Mr. Ruskin, who had mentioned it in one of his lectures. There had been columns and arches and scrolls in iron

work, and Mr. Ruskin had said that he had seen it, and that it made him wish he had been born a blind fish in a Kentucky cave. He thought afterwards that Mr. Ruskin had let him down very easily, because sometimes he could say nasty things! Sir Benjamin Baker.

Mr. MAX AM ENDE concurred in the views of Professor Pite. Æsthetic treatment was treatment which appealed to the senses, to the perception. If the designer of a bridge treated his problem carefully according to the dictates of fitness and economy, so that his work was clear to the perception of the beholder and produced in him a feeling of satisfied interest, he had treated his problem æsthetically. The design of a large bridge, especially, was a matter of much delicate and intricate thought, and if such thought was successfully conveyed to the perception of others, it might be said that no further æsthetic treatment was needed, inasmuch as what were conceived to be beautiful lines and pleasing proportions would naturally grow out of careful treatment. It was, however, desirable sometimes to bring to greater prominence those parts of a large bridge which would appear neglected when treated on strictly economical principles, and it was more æsthetic to do so by means of ornament than by a masterful elaboration of constructive detail. Such parts were, for example, the platform of the bridge, which appeared sometimes to be the least important part while it really was the most important, and the hinges of an arch, which always appeared insufficient in strength and stability. Mr. am Ende.

Mr. ST. GEORGE MOORE thought the Author had struck a false note, the only one in the whole of the Paper, in the title—"The Æsthetic Treatment of Bridge Structures." That appeared to him to imply that the bridge was to be designed first and ornamented afterwards, and that, as had been well said by other speakers, was not the true way to approach the subject. A bridge had to be æsthetically designed and not æsthetically treated after it had been designed. He had had occasion to pass the Alexander III. Bridge very frequently during its construction, and he confessed that the bridge had not been improved by the ornament. Its beauty lay really in curve and outline. Engineers ought to carefully avoid laying themselves open to Pope's criticism of the Artist and the Poet:— Mr. Moore.

> Poets heap virtues, Painters gems at will;
> And hide by ornament their want of skill.

Stone bridges had been under discussion for a great many years, and some wonderful and beautiful examples had been built. The

Mr. Moore. design of iron bridges, however, was practically a new science. He took exception to the remarks of several speakers with regard to the diagrams which the Author with great labour and perseverance had placed on the wall. Several speakers had referred to them without realising that they were engineering diagrams and not pictures of the bridges. It was absolutely impossible for the eye to see the actual structure in the diagrams. An engineer was accustomed to looking at a drawing of that sort, and it conveyed a meaning to his mind; but that an artist should look at it and complain of a want of regularity of spacing of the members rather surprised him. Mr. Read had struck the true key-note in saying that as the knowledge of the theory of ironwork construction and the knowledge of the nature of the material increased, bridges would naturally improve in appearance—that the truer the science the more closely would the rules of art be adhered to. Bridge construction and music were probably the two most mathematical sciences in existence. Any false mathematics in music produced a false note; any false mathematics in a bridge produced redundant and false members. He was sure that if engineers would apply themselves to the study of the works of recognised masters in the science of bridge construction they would improve their art.

Mr. Myers-Beswick. Mr. W. B. MYERS-BESWICK entirely agreed with Sir Benjamin Baker's remarks as to there being no difficulty in an engineer and an architect working together. It had been the practice of himself and his firm for some 30 or 40 years to work constantly with an architect without the slightest difficulty. In certain works an architect must more or less take the lead; for other works an engineer must be primarily responsible. In an ordinary bridge, in nine cases out of ten, the general mode of construction was decided by the circumstances of the case, and all the engineer could do, so far as the architecture was concerned, was to be guided in the exact line of a curve and in what might be described as ornament—chiefly applicable to the abutments or piers of a bridge. He considered that the designs shown in *Figs. 16* and *17* were very ugly, and he could not believe that either of them was necessary. Above the voussoirs of the arch there must be a road of some sort that would probably take at least the thickness of an ordinary stringcourse; there could not possibly be any difficulty in carrying the stringcourse above the voussoirs, and the parapet could be lowered or raised to any extent.

Inglis. Mr. J. C. INGLIS had been a little disappointed at the criticism of the æsthetic properties of the Britannia and Saltash Bridges, but after hearing the artist of the Forth Bridge on the principle he

had adopted—viz. fitness of a structure for its purpose, a principle which the writer of the Paper also enunciated, and one with which the meeting was generally in agreement—he had but little to say. The discussion had appeared at first, judging from the points which had been raised with regard to the Britannia Bridge, to be rather against the principles which the Author laid down. He had prepared four lantern-slides, including one of the Saltash Bridge as it appeared with its surroundings, and two of the Maidenhead Bridge, both those bridges being the work of Mr. Brunel; and if permission might be granted he would be pleased to exhibit them. Mr. Inglis.

The PRESIDENT remarked that such a proceeding was contrary to the practice observed in the course of the Institution debates; but having regard to the unusual character of the subject before the meeting, and to the fact that the discussion was now at an end, he would accede to Mr. Inglis's request. The President.

Mr. INGLIS then showed the views in question, and observed that in his opinion Mr. Brunel had fulfilled the conditions which Sir Benjamin Baker and other speakers had laid down, namely, he had followed engineering principles to their limit. He had done it himself, not deputing the work, and the results of his genius were personal results to a degree which was not often found in engineering works. A study of the surroundings of Saltash Bridge and of the Maidenhead Bridge, that was, of an iron bridge and of a stone bridge, rather traversed the statement in the opening of the Paper, that the æsthetic treatment of bridge structures had not received adequate attention in the past. Mr. Brunel's works showed that he had thoroughly understood the principles he was dealing with, and his carrying of them out point by point was as good an example of æsthetic treatment as any that could be met with in engineering. Saltash Bridge had been criticised on the ground that the centre pier was different from the others; but there was a thoroughly sound engineering reason for that departure from uniformity, and he was not aware that uniformity beyond necessity was one of those things that should be worshipped. The centre pier was founded at a depth of something like 90 feet or 100 feet below the water-level, so that it was necessary to lighten the upper part of the pier by making it in cast iron. He thought the chaste and modest treatment of the piers at the end of the tube was typical of the discussion that evening. With regard to the heaviness of the upper member of the girder tube, a false impression would be very likely conveyed by the Author's diagram, but the photograph on the Mr. Inglis.

Mr. Inglis. wall showed a logical engineering structure built 40 years ago, which he submitted to be a triumph of ingenuity. With regard to the Maidenhead Bridge, that was another example of a plain engineering design of a bridge with two spans of 128 feet each. Ornament was almost absent, but the exceeding beauty of the economy in effect was quite exceptional. There was a grand simplicity about the treatment of the arch, which was lamentably wanting in a structure so highly spoken of as the Alexander III. Bridge. In conclusion, he would exhibit a slide of a tunnel-mouth built by Mr. Brunel. It was rather a contrast to that engineer's usual structures, and he exhibited it rather as a curiosity, showing how a great engineer could depart from the true lines and really play with the æsthetics of architecture.

The President. The PRESIDENT thought the discussion had fully justified the Council in selecting the Paper for reading. He had been greatly pleased to see so many architectural friends present, and had been particularly delighted in listening to the able and eloquent speech of Professor Pite, the son of Mr. Alfred Pite, an old confrère of his in Brazil 40 years ago.

The Author. The AUTHOR, in reply, desired to acknowledge the vote of thanks accorded to him and to express the pleasure he had felt at the Paper and discussion having been the means of eliciting so many valuable expressions of opinion from members of both the engineering and architectural professions. Some speakers had complained of the fact that elevations of the bridges had been provided instead of perspective views. If it had been remotely possible to place perspective views of all the bridges on the wall he would have done it; but it would have been an utterly impossible task. That point had been already foreseen and mentioned in the Paper, and was the principal reason why lantern-slides of several of the more important bridges had been exhibited before the discussion. Some speakers also had appeared to think that all the bridges in the diagrams were put forward as examples of æsthetic design. He did not claim anything of the sort. Careful reference to the Paper would show that a few of the bridges, and a few only, had been emphasized as truly æsthetic structures, in his opinion. Those which he had attempted to emphasize in that manner were Figs. 3, 5, 21, 31, 33, which he specially admired, 37, 40 and 48. Most of the remarks made had almost necessarily tended to the expression of individual opinion on the points at issue rather than to actual criticism of the subject matter, and many of those remarks had been very conflicting. With reference to Mr. Elliott Cooper's remarks, the

design shown in *Fig. 7* was distinctly mentioned in the Paper as being preferable to that of *Fig. 6*; incidentally he might mention that *Fig. 6* had been taken from an existing bridge. With regard to the bridge over the Blaau Krantz ravine, it had been stated that the chief reason for the adoption of that particular design had been the necessity for erecting it without scaffolding. In the absence of more detailed information, he ventured to think that an arched bridge of the same span might have been erected by overhang, under the same conditions, and would probably have had a much better appearance. An allusion by Mr. Caröe to the Conway Bridges had raised the question of the propriety of building bridges with defensive towers or abutments. He thought many instances might occur in which such a mode of procedure would be not only desirable but necessary, as, for example, bridges over rivers which constituted important political boundaries, or in positions of strategic value. It was a very usual proceeding to fortify the abutments of such bridges, and the Dufferin Bridge at Benares, and that over the Rhine at Coblenz, might be mentioned as examples. Exception had been taken to the remark as to one material being presented in forms more suitable for another. Certainly no one would wish to dispute the beauty of the distinctive features of classic design executed in stone, yet the special features referred to might with equal propriety be constructed in wood or in stone without violating the suitability of either material for the purpose, and this was probably an important reason why such forms of architecture did not appear incongruous. When, however, examples of bent wooden construction, and even such details as pins, notches and cotters were reproduced in stone, as was the case in many Eastern buildings, the effect might be striking, but it was scarcely pleasing. It was the inadvisability of thus going to extremes which had been implied in the Paper. The Author might be permitted to give a brief quotation from Fergusson[1] as bearing on the subject:— The Author.

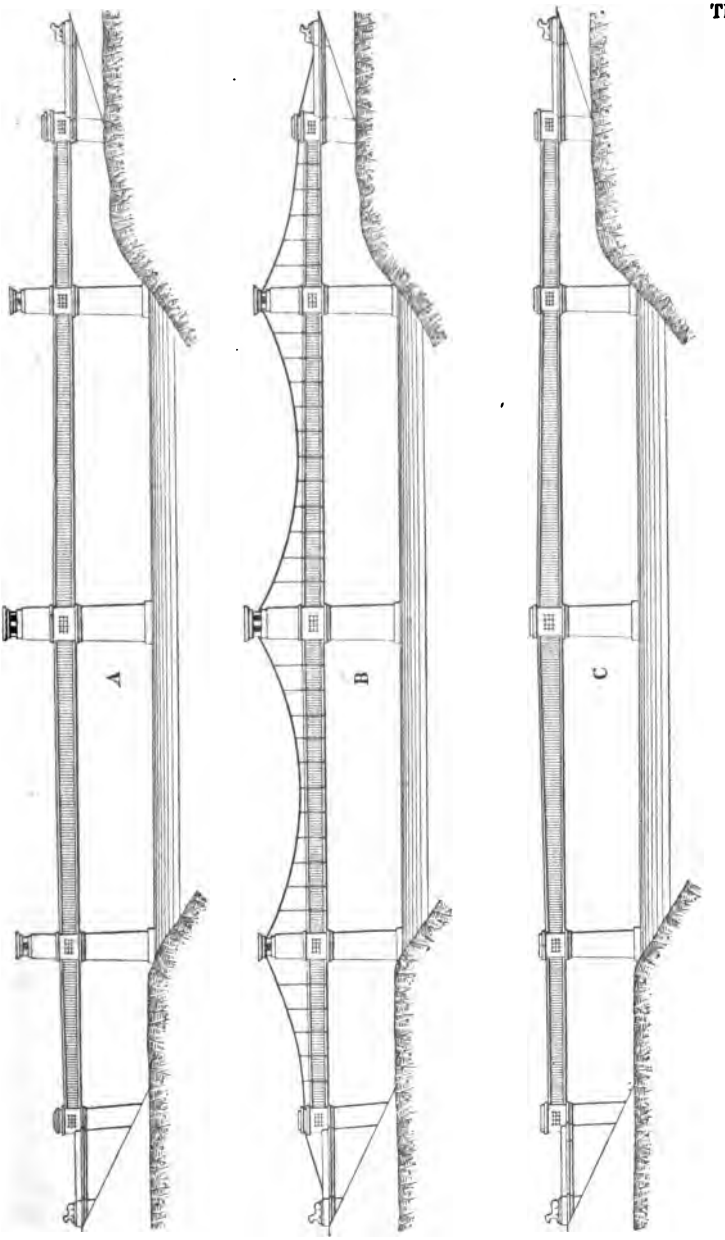
"It is only in the infancy of stone architecture that men adhere to wooden forms, and, as soon as habit gives them familiarity with the new material, they abandon the incongruities of the style, and we lose all trace of the original form, which never reappears at an after age."

Mention of the effects producible by painting structures had been purposely omitted from the Paper. It was obvious, however,

[1] "History of Architecture," by James Fergusson, vol. i. p. 234.

The Author. that the particular colour applied to a metal structure might exert a considerable influence on its appearance, and not a few structures offended the eye in this respect. The viaduct with abutment-piers, of which Mr. Read had submitted an illustration, was certainly very pleasing, the principal reason being that the abutment-piers occurred at very frequent intervals. Their suitability in an exceptional case such as this had been admitted. Several speakers appeared to hold the opinion that very large iron structures could not possibly be regarded as æsthetic. He thought Sir Alexander Binnie had given a very lucid explanation why such opinions were entertained, in apprehending that the public did not yet sufficiently appreciate the meaning of those structures and the skill evidenced in their design. Much of the discussion had almost necessarily turned on the relation between the professions of engineering and architecture. In that connection it was satisfactory to notice that many modern works, especially in France and Germany, furnished examples in which most happy results had been achieved by co-operation between the architect and the engineer; and the members had had placed before them, in the design for the Victor Emmanuel memorial at Rome, an excellent example, such as would scarcely be looked for as the individual work of either an engineer or an architect. At the same time he ventured to think there was no adequate reason why the engineer should not make himself familiar enough with the essential principles of architecture to be able to successfully cope with any ordinary difficulty that might present itself. It seemed, however, distinctly desirable, where engineering proposals included a considerable amount of architectural design, that the assistance of an architect should be requisitioned. He was pleased to find so many members of the architectural profession agreed with him as to the excellent appearance of the masonry parts of many bridges which had been designed wholly by engineers. He thought also that the massive masonry piers and towers of many bridges, although devoid of architectural detail in the ordinary acceptance of the phrase, yet exhibited very successfully the application of the principles of what might be called engineering architecture. In instituting comparisons between British and Continental bridges, frequently to the detriment of the former, it should be remembered that opportunities for the erection of imposing bridge structures were much more numerous on the Continent than in England, and that in many instances such works were undertaken by the Government and carried through on a more lavish scale of expenditure than

The Author.



Figs. 52.

The Author. was the case at home. The remarks of Sir Benjamin Baker upon the Britannia Bridge were of especial interest. Mr. Fairbairn, whilst condemning the use of chains as a permanent auxiliary support for the tubes, had yet admitted their possible value as a temporary aid in the construction, and this consideration, apart from Mr. Hodgkinson's advice, might have warranted the carrying up of the piers to their present height. Without altering the design of the masonry, he had endeavoured in *Figs. 52* to show, in the one case (B), what might have been the appearance of the bridge had auxiliary chains been employed, and in the other (C), its possible appearance had the employment of the chains never been suggested. It was perhaps fortunate, all things considered, that the bridge had been left in its present state, as the presence of the chains, although creating a by no means ugly impression, could scarcely be reconciled with the type of girder to be supported. On the other hand, had the piers been built as in *Figs. 52* (C), or more probably been terminated at the level of the lower boom, nothing would have redeemed the structure from taking rank with the very large class of ordinary supported-girder bridges.

Correspondence.

Mr. Bache. Mr. ALFRED BACHE remarked that, where a steeply inclined roadway was carried over a stone bridge, in which the bed-joints of the masonry adhered to the horizontal in the spandrels and face-work generally, it was suggested at page 17 to adopt a neat stepped parapet, in which the courses might retain their horizontality. Such an outline for the parapet, he feared, would present a somewhat bald appearance; and he suggested that, if the gradations were marked by a castellated or embattled outline, instead of by bare steps, the general effect would be enhanced and relieved of stiffness, while the courses would still be kept horizontal throughout the entire length of the sloping parapet. In *Fig. 18* the appearance, he feared, would hardly be improved by increasing the height of the land arches. The objection to the present design seemed to him to be the apparent weakening of the abutments by the occurrence of the existing land arches just where the thrust of the main arch seemed to come. If the land arches were carried up higher behind the spandrels of the main arch, the apparent

weakening of the abutments would seemingly be aggravated thereby. The land arches, presumably a necessity, appeared indeed to form the one objectionable feature in what looked otherwise an admirable design. The Brooklyn Bridge [1] was referred to in the Paper as an example of a rigid suspension bridge presenting a satisfactory appearance. It would be of interest, he thought, if a sketch of it could be added to the illustrations accompanying the Paper, in order that the Author's eulogy might be fully appreciated by those who did not carry this particular bridge in their mind's eye. No view of it seemed hitherto to have been included in the Institution "Proceedings," notwithstanding the renown of its river span of 1,595½ feet. Among the lofty viaducts in iron and steel which were carried over deep valleys on built-up metal piers, it might not be out of place to recall one of the earliest and most elegant in this country—namely, the Crumlin Viaduct,[2] near Newport, Monmouthshire, carrying the Great Western Railway between Pontypool Road and Tredegar Junction across the valley of the River Ebbw in seven spans of 150 feet each at a maximum height of 200 feet. The main girders were Warren trusses, each 14½ feet deep. The piers were built up of hollow cast-iron columns braced in tiers, and tapered upwards with a batter which gave the impression of stability combined with lightness. The whole structure, completed in 1856, presented a welcome appearance of harmonious design, and stood out in highly pleasing and artistic contrast with its romantic surroundings. Regarding the Menai Suspension Bridge as almost outside the pale of æsthetic criticism, the Author added that the appearance of the land arches was especially acceptable from their exceeding beauty of proportion. A contrary opinion had been expressed half a century ago respecting the pyramidal piers and the arches, in the following words [3]:— Mr. Bache.

"If this masonry merits attention on account of its bulk and height—for the piers are 153 feet high—it cannot be said to do so on account of any tasteful disposition; as a piece of architecture it contrasts strikingly with the simple and elegant stonework of Fribourg Bridge. . . . The curve of the chains, at all times a beautiful object to the eye, lends to it a grace which makes it an orna-

[1] Minutes of Proceedings Inst. C.E., 1877, vol. li. p. 296; and 1883, vol. lxxii. p. 9.

[2] Minutes of Proceedings Inst. C.E., 1880, vol. lxiii. p. 189.

[3] "Dynamics, Construction of Machinery, Equilibrium of Structures, and the Strength of Materials," by G. Finden Warr, pp. 221 and 223. London, Robert Baldwin, 1851.

Mr. Bache.

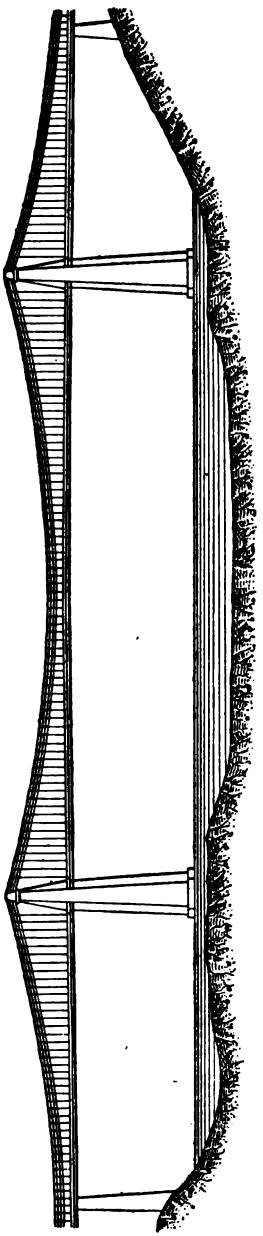


Fig. 53.

ment to the noble strait and its charming woody banks; to this effect however the side arches add nothing, as, like the pyramids, they are by no means pleasing or well formed."

Applying however the principle laid down by the Author for the first of the two alternative ways in which a truly æsthetic result might be achieved, it seemed to Mr. Bache that the land arches were wholly redundant, and that the elegance and beauty of proportion of the structure as a true suspension bridge would be enhanced by their absence. The length of the longest roadway, over the four land arches on the Anglesey side, was not more than half the main span of 580 feet;[1] hence the chains, which were strong enough to carry the main span, were strong enough to carry the two side spans also, without the land arches. In the existing structure, where the land arches carried the roadway, the rods which supported the central span lost their suspending function over the land arches, and became tie-rods or holding-down bolts for constraining the chains to keep to the proper catenary curve over the land arches; they thus sustained the same tension as they would have had to do if they had been made to carry the roadway of the side spans. The land arches were consequently superfluous; and the improved artistic appearance of the true suspension bridge, which would be realised by their absence, was illustrated by *Fig. 53*, as contrasted with Fig. 40, Plate 3. The elegance of the Conway Suspension Bridge was not marred by any arches in the approaches at either

[1] Minutes of Proceedings Inst. C.E., 1846, vol. v. p. 32.

end, though obscured by the adjacent tubular railway bridge. A beautiful example, unimpaired either by side arches or by any other incongruity, was the Clifton Suspension Bridge,[1] of 702 feet span, over the Avon at Bristol, which resembled and rivalled the celebrated Fribourg Suspension Bridge [2] crossing the valley of the Sarine in a span of 896 feet. Mr. Bache.

Mr. M. J. BUTLER considered that the Author had laid down with truth and accuracy the principles which should guide an engineer in the design of any structure. Nevertheless he ventured to submit that many of the criticisms made against the lack of the beautiful in engineering construction were not based upon right principles. "The eye seeth only what the eye bringeth the means of seeing," hence a student of the art of the past, when stone formed the chief building material, looking at a modern steel structure with its rectangular lines, was apt to consider the latter an ugly structure. Stone did not lend itself to rectangular construction, and the natural way to utilise the strength of the material was to put in arches of some form of curve: as nearly all natural surfaces were curved it had grown to be almost a maxim that to be beautiful a structure must be of the arch type. Yet to an engineer cognisant of the forces at work, and of the structural arrangements required to resist them safely, the curved surface might be ugly. It would seem that any structure designed on lines of true economy, with the utmost simplicity and with the fewest number of parts, was a beautiful thing. Yet such designs as the Sukkur and Jubilee Bridges illustrated in the Paper were irremediably ugly. The new Inter-Provincial Bridge at Ottawa, was by no means a beautiful one, although the site was one which demanded some attention to æsthetics, lying as it did under the shadow of Parliament Hill. The long flat triangular lower chord of the cantilever was the offending member. The general appearance also lacked a satisfactory balance about the great span. The bridge itself was a remarkable and notable one, but it failed in the matter of beauty. Obedience to the old rule, "Decorate your construction, but do not construct decoration," would generally result in satisfactory treatment. Mr. Butler.

Mr. THOMAS C. CLARKE, observed that it had been said by Sir Henry Wotton that the essentials of good building were "firmness, commodity, and delight." The essentials of bridge construction were the same. Firmness was indispensable. The adaptation Mr. Clarke.

[1] Minutes of Proceedings Inst. C.E., 1867, vol. xxvi. p. 243.
[2] *Ibid*, 1881, vol. lxvi. p. 389.

Mr. Clarke. to uses, which Wotton called commodity, came next. The æsthetic quality, which he had called "delight," came from just proportion, first of all, and next from that ornamentation which was derived from the actual construction, modified with elegance, but not departing from truth. It differed greatly from some of the architecture of to-day, which was deceptive, and tried to make a thing look like something which it was not—a humble chapel like a Greek temple, for instance. On the other hand, the soul of an ancient style might be infused into a modern building, as was seen in the Town Hall at Liverpool, which was as fine a specimen of the Greek style as Athens itself could show. Fig. 3, was given by the Author as an illustration of the true treatment, while Fig. 4, was a kind of tailor's architecture with too many trimmings. The Alexander III. Bridge had a graceful outline, and would have been fine if its architect had known when to stop, and had omitted the decorative treatment of its spandrels. Festoons did not belong to engineering construction, as they were merely applied ornamentation, like that on a lady's dress. For bare and unadorned ugliness the Sukkur Bridge surpassed all others, while the Britannia Bridge was one of the finest specimens of bridge architecture in the world. Roman bridges and aqueducts showed both scientific and æsthetic construction. The massive construction of the Roman bridges made them very effective. The long lines of round arches of the aqueducts were not monotonous, and harmonized with the lines of the landscape. The massiveness of ancient architecture gave a great effect of strength, but this style could not be followed in the present time. The modern engineer was governed by considerations of economy, and did not dare to use more material than his strain-sheets called for. The four great columns supporting the dome of St Peter's were each of them as large as the church of Trinita dei Monti at Rome. An engineer could have carried the weight of the dome by four steel columns 6 feet in diameter, but every one would have cried out in horror at the sight. Perhaps Emerson had had a suspicion of this when he had said that the architect of Saint Peter's "builded better than he knew." Engineers said that architects put in too much material, while architects contended that engineers did not put in enough to answer æsthetic requirements. It was what Voltaire called "Le superflu, chose necessaire," that gave architecture its beauty. The most successful union of æsthetic and scientific construction ever reached was found in the northern mediæval cathedrals. It would be an excellent subject for a prize essay for students, to produce from actual measurements and calculations strain-sheets of such

cathedrals as those of Amiens, Rheims, or of Westminster Abbey. Ruskin had once said that machinery was hideous. If so, it was because it was a bare skeleton. A man, a horse and a bird were types of the best-designed machinery, and they had beauty because their skeletons were draped with flesh. A girder-bridge was ugly because it was a bare skeleton. The examples of open-work steel construction given by the Author seemed to show this. Some things, however, could be done. For short spans Nature's method could be followed; a useful skeleton could be built within and covered with concrete disposed in graceful lines. As an example of this he called attention to the Memorial Bridge at Washington.[1] When the span of the arch became too large for this treatment, its own lines, if of due proportion, would give it sufficient æsthetic beauty, as, for instance, the arched bridge at Niagara with spandrel-bracing. Where a level girder-bridge had to be used, the best treatment was to make it as simple as possible, and to concentrate all the ornament on the balustrade and cornice which was near to the eye. An example of such treatment was found in the Girard Avenue Bridge at Philadelphia.[2] Where the requirements were for a long low bridge with no movable draw, the bridge at Geneva near the outlet of the Lake, consisting of many segmental arches, was one of the best examples. If bridges of very long span were necessary, the graceful outline of a suspension bridge, not distorted from its natural curve by bracing, gave the most satisfactory result. If the span was within the limits of cantilever construction, the same curves should be followed, making the central suspended span level, and tangential to the curves, and by no means with an arched upper member.

Mr. Clarke.

Mr. E. G. Coker remarked that the view expressed by the Author that a pleasing effect in a bridge structure might be produced "in an otherwise distasteful appearance by a judicious application of ornament in such a manner as to hide the bare constructive detail, without at the same time effacing the leading features of the general structural design" did not appear to be a commendable one, as a structure if not beautiful in itself could not be made so by any application of ornament. One of the essentials of beauty in a bridge structure was to attain the simplest and most economical distribution of material which expressed the purpose of the structure. The evolution in the

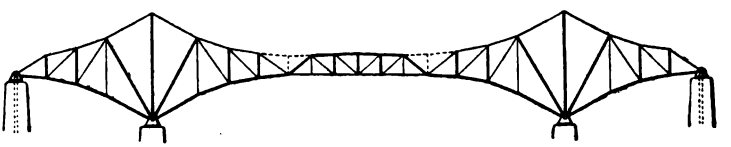
Mr. Coker.

[1] *Engineering Record*, 13 October, 1900.

[2] *Engineering*, vol. xx. p. 379.

Mr. Coker. design of bridges tended to produce a form which satisfied this criterion, and during the last few years this development had been very marked in the design of cantilever bridges. Recent designs by American engineers had shown that some agreement had been arrived at with regard to this type, and although it was probably only a stage in the march towards perfection, yet it appeared to be a great advance upon early work, and to fulfil the condition mentioned above. The characteristic features of recent American designs were illustrated by a diagram for a through bridge, *Fig. 54.* The purpose and design of the bridge were here strongly marked; the break of continuity at the ends of the cantilever arms was emphasized, as it should be; the gradual diminution in depth of the anchor- and cantilever-arms conformed to regular curves which merged into those of the central girder; the balance of the arms was preserved by their equality; and the appearance of stability was assured by massive end piers.

Fig. 54.



Mr. Crowell. Mr. FOSTER CROWELL, of New York, thought it might be admitted that the quality of beauty has not apparently been sought for usually by the bridge designer, but it was questionable whether that had been due so much to apathy and a limited choice of material, suggested by the Author, as to undeveloped conditions of popular taste and appreciation in this regard. As a rule, and confining his remarks to his own country, he thought that the engineer, in designing a bridge, looks primarily at but three things, which were capacity, consistent strength, and economy; and when the structure had been completed, the criticisms and discussions of his brother engineers were directed to these three features only. To point out the ugliness of a man's bridge would be viewed much in the light of a personal attack, and certainly, at the least, would be deemed hypercritical. On this account he considered the Author's temperate and thoughtful presentation of a plea for æsthetic treatment to be both timely and valuable; and his references to the American examples which he included in his comments, and with which Mr. Crowell was familiar, indicated thorough study and accurate observation. It did not follow,

however, that because an engineer had built a bridge which was ugly from the æsthetic point of view, he had not done what was distinctly the best thing to do under the governing circumstances, nor that he himself was either unaware or disregardful of its short-comings. Moreover, many bridge engineers emphatically refused to consider beauty, in a sensual sense, as a necessary adjunct of design; they claimed that there was such a thing as an intellectually perceived beauty of usefulness, which consisted in the evident application of successful means to an end, and that "whatever looks right is right"; that shibboleth being the engineering equivalent for the old proverb, "handsome is as handsome does." It was needless to point out its error, or to remind members of the profession that such perceptiveness, where it existed, was an educated faculty not shared outside of a limited class. Ruskin's analysis of beauty to the eye, and its effect upon mind and character, was useful as a negative to the proposition, and it was sufficient to turn to any other department in architecture in order to be convinced of its falsity. Yet it probably had no little influence in perpetuating ugliness in bridge design. Finally there was natural conservatism to contend with. In America there were few beautiful bridges, among the larger structures at least, but already there were abundant signs of an awakening by the public to an appreciation of the usefulness of beauty in many ways; and in some of the more recent bridge-designs a disposition had been manifested no longer to ignore the claims of beauty *per se* as an enhancement of excellence therein; public bodies and the press too had begun to demand that bridges should be manifestly beautiful. Happily, in America, the era of redundant, so-called ornamentation, to which the Author had referred, with all its atrocities of added extraneous "decorations," or disguises, or concealments of the real design, was passing away. Such monstrosities were no longer possible, for instance, as the Callowhill Street Bridge over the Schuylkill, in Philadelphia, a 350-foot rectilinear iron-truss, double-decked single span, which was boxed in with sheet iron and painted to simulate cast-iron, so as to appear as a colonnade viaduct; and as if its purpose were to support the upper deck with a heavy stream of traffic whilst its feet stood upon nothing but air, the ridiculous effect was further emphasized by the very pronounced camber of the truss, to which the colonnade conformed. This treatment must not be taken as indicative of usual eccentricities of American design, as it was probably an extreme case, but it served to illustrate the depths of engineering depravity possible, even in a city like Philadelphia. With the passing away

Mr. Crowell.

Mr. Clowell. of the meretricious and extraneous parasitic decorations had come a vast improvement in workmanship and dimensioning of all classes of metal bridges, so that even the plainer forms of structure had acquired a neatness and fitness that was akin to elegance. Taking all things into consideration, then, although the bridges of the past were, as a rule, far from beautiful, there would seem to be ground for the hope that as the engineer became convinced of the existence of popular appreciation of beautiful bridges he would find means to gratify it; for, to paraphrase Keats, "A bridge of beauty is a joy for ever."

Messrs. De Rudder and Van Bogaert.

Messrs. DE RUDDER and VAN BOGAERT of Brussels, remarked that the principal, and perhaps the only reason why the older masonry bridges and modern works in metal were not æsthetic, was that they had been designed by engineers who had no notion of Art, and it must be admitted that it would be surprising if it were otherwise. The course of scientific studies needed for the engineering profession, already long and arduous, did not permit an engineer to study Art, and to become an artist as well as an engineer. It must not be forgotten that to excel in any art it was necessary for a man to devote the whole of his time to it. It was easier to acquire enough knowledge and taste to be able to judge the work of an artist; but even this capacity was by no means common, and it must be admitted that an engineer possessing, as the result of a study of Art, sufficient taste to judge an artistic work of construction, was not often met with. In fact, they considered that the artist-engineer was a myth, and the æsthetic engineer a *rara avis*; but they hoped that the future held in store many of the latter, and even one or two of the former. This did not prevent the rules indicated by the Author from being useful, and they would perhaps restrain engineers from erring very seriously; but no amount of observation of rules would produce a work of art. Turning to some of the points raised in the Paper, they did not consider that the design of masonry bridges had reached its highest point; they maintained that in the past 30 years great progress had been made in this form of construction and in its architectural treatment, and they cited as instances the bridges of Lavour, Antoinette, Castelet, Céret, and Gour-Noir in France, having openings varying between 40 metres and 60 metres; the almost similar viaducts of Jaremeze, Worochts, and Jamna in Austria; the concrete bridges in Wurtemburg with hinged arches; and lastly the Luxemburg viaduct, with a span exceeding 80 metres, in course of construction. Apparently engineers were returning somewhat to masonry bridges, which

had many advantages over those in metal. As the Author stated, their appearance was better, and this was due to the great simplicity of their lines. Moreover they scarcely afforded an opportunity for the engineer to go very far wrong. Large iron bridges and viaducts, with some exceptions, had the appearance of huge scaffoldings, the eye losing itself in the crowds of thin lines, which intermingled and crossed one another in every direction. It was impossible to judge such a structure from a small drawing of its elevation; the simple lines of the drawing became very complicated in perspective, and the anticipated effect was not realised. The metal bridges which were most satisfactory to the eye were arched bridges without spandrel-bracing, and unstiffened suspension bridges. These two types had very simple lines which, exclusive of the arch, ran in only two directions, viz., horizontal and vertical, like masonry bridges. Messrs. De Rudder and Van Bogaert.

Professor T. CLAXTON FIDLER observed that it had been the fashion with art-critics to assume that engineers were indifferent to the æsthetic treatment of their structures, but it was quite certain that every engineer would feel a deep instinctive interest in the subject which the Author had introduced, although he might shrink from laying down any set of principles that would pretend to rank as canons in art-criticism. It was indeed delightfully impossible to frame any rules for the æsthetic treatment of bridge structures. Architects had generally agreed that every kind of constructed ornamentation was bad, and yet the force of lingering association was constantly impelling them to reproduce some form of inappropriate ornament which they admired in bygone styles of architecture. The dentils and triglyphs, which seemed to have sprung from an extinct style of timber construction, were reproduced as "constructed ornament" upon the stonework of Greek temples, and if they re-appeared once more in cast iron upon the sides of a nineteenth-century bridge, the engineer might at least feel that he was sinning in very good company with the builders of the Parthenon. Amongst engineers, however, it would generally be felt that the greatest dignity in bridge architecture was that which was sometimes happily attained in a structure of unadorned simplicity, in which every line told by reason of its perfect fitness. The Eddystone Lighthouse might be confidently referred to as an engineering structure which expressed this feeling with the highest refinement. And with a similar simplicity of outline the builders of stone bridges, from the Romans downwards, had succeeded in producing structures Prof. Fidler.

Prof. Fidler. which were almost always picturesque, while some of them must rank as fine architectural designs. It could scarcely be said, perhaps, that the ironworker had maintained the same degree of success since the time when he had had to take over the functions of *Pontifex Maximus*, but he had had many difficulties to contend with. It had been impossible to preserve the broad simplicity of structural form—except in the single case of the chain suspension bridge—and in most cases the structure had become a complicated tangle of struts and ties, possessing no eloquence of structural meaning for the general observer. The fitness of each part for its work had not been sufficiently apparent to become an element of beauty, and indeed had been obvious only to the technical mind saturated with text-book formulas. Perhaps it was just this dominance of scientific ideals which had formed the main difficulty; for the æsthetic effect of any structure, good or bad, depended upon what it revealed as to the mind and intentions of the constructor, and if it revealed nothing but what might be suggested by a diagram in graphic statics it could hardly be beautiful. But the ironworker had very good reasons to urge in his defence. He had been so much occupied hitherto in the problem of building strongly and building economically that he had been unable to allow his mind to wander from these inexorable conditions. Under freer and more favourable auspices it was still possible that he might develop a worthy style of architecture in steel, and the structures of the present transitory age might then be described, amongst other antiquities, as examples of the "text-book" style of bridge architecture.

Mr. Fülscher. Mr. FÜLSCHER, of Berlin, considered that the Author's suggestions in regard to the architectonic treatment of bridge structures, whether of stone, or iron, or both combined, were well worthy of consideration. For many years past it had been, he might almost say, a rule in Germany that, in the preparation of designs for bridges of considerable size, especially where it was a question of suiting a structure to the character of the surrounding landscape or of existing buildings in the vicinity of the bridge, the engineer should unite with a capable architect, so that all questions relating to the treatment of details of construction fell to the share of the latter. In this way the designs of the bridges over the North Sea and Baltic Canal referred to in the Paper, and, so far as he was aware, also of all the newer bridges over the Rhine which were of notably handsome appearance, had been evolved; and as it was the exception for an engineer to be also a master in archi-

tecture the general adoption of this practice might be recommended. Mr. Fülscher.

Mr. A. Goupil. Mr. Goupil, of Paris, congratulated the Author on the happy manner in which he had treated a delicate subject. As an example of a form of bridge construction suited to various spans and combining lightness of the girders with æsthetic treatment of outlines, he forwarded a short description of the viaduct carrying the Paris-Versailles line of the Chemins de fer de l'Ouest over the Rue de Alésia, in Paris, constructed on a system which had been used by the company in special cases, and termed a *pont à béquilles*. The elevation of this viaduct was shown in *Fig. 55*. The girders were practically straight and were united to vertical pillars, the angle between them being rounded off according to the necessities of each case. With this system it was possible to give a very small depth to the floor, and consequently to reduce the number of cross-girders or even to omit them. In the example illustrated, which had a clear span of 20 metres, the depth of the girders at the middle was only 1·1 metre although the load was considerable, the sleepers being carried on ballast.

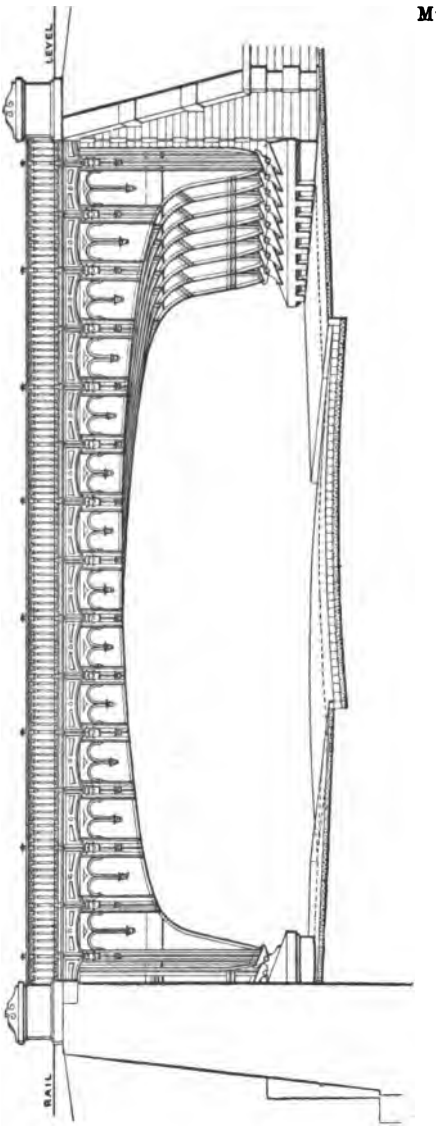


Fig. 55.

Mr. Gribble. Mr. T. G. GRIBBLE thought it was impossible to criticise the appearance of large bridges by means of skeleton diagrams. The irresistible sentiment of admiration which arose from the sight of a great achievement of human intelligence and skill was not evoked by a collection of geometrical figures. Criticism, without having seen a bridge and retaining in the mind's eye a vivid picture of it and its surroundings, was criticism not of the structure but of its skeleton. He could not at all endorse the criticism which disparaged the towers of the Brooklyn Bridge. Whether from the shore or from a steamer, the bridge had left upon his mind an indelible picture of all that was chaste and beautiful. The Sukkur Bridge had been the subject of a great deal of severe criticism on the part of the æsthetes. He could not pretend to offer any opinion, because, like many of its severest critics, he had only seen it when in course of erection at the Isle of Dogs. He could, however, quite understand an engineer feeling admiration for the actual structure if he were looking at the great span from a suitable point of view. Æsthetic criticism must be intelligent, and similar to a true appreciation of Nature. Imagine a naturalist and a hairdresser beholding for the first time a hippopotamus, the man of science delighted, the barber disgusted. Then, with intelligence, there must be also trustfulness in criticism. Where a great structure lacked symmetry in some particular point, it appealed by its own merits for confidence in its designer. It would be unworthy of the engineer to charge him with fancifulness, and therefore the intelligent mind at once began to seek out the cause, and while so engaged the eye forgot to be offended. Again, æsthetic criticism must be up to date. He quite agreed with Mr. Blyth's criticism of the Glasgow Corporation in their renewal of Telford's Bridge at the Broomielaw, described in his recent Paper.[1] If their veneration for the antique had gone no further than to preserve or widen the structure it would have been very commendable in hardheaded business men, but to "resurrect" an antique structure was, he thought, quite indefensible, not to say snobbish. Present-day bridges could not be looked at with the eye of a Michael Angelo nor even of a Telford; the present was the Iron Age, and had its canons of taste equally with the Byzantine or Gothic Ages; canons in which utility greatly transcended adornment, but which embraced symmetry, simplicity and appropriateness. But although bridge-building should be strenuously defended

[1] Minutes of Proceedings Inst. C.E., vol. cxliv. p. 6.

against unintelligent criticism, it might be frankly admitted that much of the unsymmetrical outline and ugliness in detail was avoidable. Comparing for instance the Viaur Viaduct with the Niagara Falls and Clifton Arch, the reason given by the engineer of the latter structure for the painful side spaces was that the view of the Falls might not be obstructed by the bridge. Surely the tourist would have forgiven him if he had put up a bridge of the Viaur type! Mr. Gribble.

Mr. W. R. HUTTON, having in mind the adage, *De gustibus non est disputandum*, thought it was unnecessary to comment in detail upon the Author's rules for æsthetic design of bridge structures. Some of them would condemn the most admired bridges of ancient and modern times, while many of the illustrations represented works which were not recognised as models of æsthetic design. In bridges of masonry the general arrangement, the proportions, and the method of construction were fundamental, and these were generally sufficient to produce a good effect. The arch should be detached from the spandrels by a marked projection or otherwise, the level of the roadway should be indicated by a string-course more or less moulded according to the conditions of the case, and a long line of parapet, unbroken by pedestals or supports, should be avoided. The straight truss, or ordinary cantilever, for railway or highway use was, as Mr. G. S. Morison had expressed it, a mere tool of transportation, and, as a rule, but little care was given to its æsthetic effects. The cantilever was popularly considered the most intractable form. But the possibilities of art were very great. An art-critic who wrote upon bridges had asked if a handsome cantilever bridge were possible. On being referred to the Pont Mirabeau in Paris, he had declared it to be the most beautiful bridge ever built. In metal arches the Author's test seemed to consist in dissimilarity to a masonry arch, and as, in the latter, the roadway could not readily be carried below the soffit of the arch, he selected the Grünenthal Bridge, which possessed that merit, as the typical æsthetic design. The similarity of the St. Louis Bridge to a stone arch was not easily perceived, although the Author recognized it. It was objected to this and to the Washington Bridge that the proportion of rise to span was such as was frequently observed in masonry structures, and the crowding of the spandrels with vertical supports emphasized the resemblance. The Washington Bridge also unfortunately required stiffeners on its broad web, and flanges to connect its segments, and these seemed to complete the deception. Happily these bridges stood upon their own merits and needed no defence. Yet one word might Mr. Hutton.

Mr. Hutton. be written in explanation. The solid web of the Washington arch was characteristic of solidity and repose. If it had been a braced rib of open work like the Niagara Falls and Clifton arch, it would have been proper to show it as resting on the pin. With the solid web, it was essential to its character that it should be carried full width to the skewbacks. There was no deception, the pin being plainly indicated by the converging flanges of the rib and by the heavy framing of the pedestals. In his remarks on the magnificent Niagara Falls and Clifton arch (Fig. 32), the Author observed that in the actual bridge the rectangular panels were of course provided with diagonal braces. If the rectangular panels referred to were those of the spandrels in elevation, they were, of course, not provided with diagonal braces, which would be foreign to the character of the construction.

Prof. Johnson. Professor J. B. JOHNSON was very much gratified to find that the subject was beginning to receive the attention it deserved at the hands of engineers. No class of citizens merited such severe condemnation for outraging the artistic sense of the cultivated portion of the people as civil engineers in their designs for bridges. A bridge was usually placed in a conspicuous position, where, of necessity, it attracted observation and invited criticism; and the relative permanence of the structure also added to the necessity for careful designing. On the contrary, many of the ablest civil engineers, in America at least, had ignored and flouted all claims upon them for artistic effect, and had rather taken a savage delight in perpetrating monstrosities and thrusting them upon a long-suffering public. It was high time the members of the profession should protest against such indifference, for the protection of their own reputations and in the interests of a more wholesome public sentiment in such matters. As early as 1866, Professor R. Baumeister had begun writing vigorously upon this subject, but, as his works had not been translated into English, his writings had had little influence in English-speaking countries. When Professor Johnson, as joint author, had published a work on framed structures [1] in 1893, a chapter, prepared by Mr. David A. Molitor, had been devoted to this subject, and this had been said to be the first attempt in the English language to treat the subject of the æsthetic designing of civil engineering structures. Mr. Molitor had drawn largely from Baumeister and other German sources, but had added considerable original matter. Since the publication of this work a very noticeable improvement

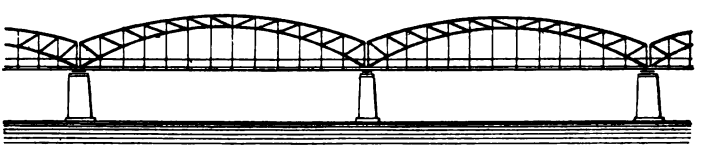
[1] "Modern Framed Structures." John Wiley and Sons, New York.

had been effected in America in the artistic design of bridges, and it was believed this could be largely traced to the chapter on that subject. It would require, however, long-continued agitation and considerable education in this field before engineers would attain to a satisfactory standard in æsthetic designing. He could in general heartily endorse the views of the Author as expressed in the Paper. Prof. Johnson.

Mr. G. KEMMANN, of Berlin, observed that the able manner in which the subject of the architectural treatment of bridges had been dealt with by the Author called for but few remarks. In Germany men of the highest rank in the profession as it had stood about two decades ago, like Gerber and Schwedler, had paid the greatest attention to the economical side of the art of bridge-building, but had hardly considered the question of beauty to be an all-important one. Gerber's bridge over the Main at Hassfurt, he believed, had never yet been surpassed in the matter of unsightliness. The principle of placing in an iron bridge only exactly the amount of material absolutely required by a special load-diagram ruling at the time of designing had been superseded. The consideration paid to future needs and the increase in wealth had gone far to strengthen the influence of those who were striving after the extended application of the rules of æsthetics to this class of engineering work; but the railways in Germany were now suffering to a certain extent from the consequences of a wrong policy, and were obliged to strengthen their structures to meet the increased axle-load of the engines. As to the metal arch, which above all lent itself to artistic treatment in bridge design, he might say that in Germany the construction of metal arch bridges had been developed on a large scale, and that that country surpassed all others in the number, variety and perfection of such structures; whereas the suspension bridge, though also exceedingly well suited for artistic treatment, had not come to the front at all. The Müngsten Bridge and its successors, and the Niagara Falls and Clifton Bridge, gave proof of the progress in the science of working out strains. They testified to the application of modern scientific rules, which opened up a wider field for artistic treatment. In this direction a trussed arch with a tie rod was much in favour in Germany. A charming example of such an arrangement was to be seen in Berlin (Brücke am Mühlendamm); large span bridges on the same principle were those over the Süder Elbe between Harburg and Wilhelmsburg and over the Mosel at Trarbach (*Fig. 56*). Mr. Lauter, of Frankfort-on-Main, deserved not a little praise for Mr. Kemmann.

Mr. Kemmann. having introduced a novel feature into the construction of street bridges with several openings crossing rivers. He gave the platform of the bridge a parabolic form, with a certain rise in the centre. Gaining thus in clear height above water-level, he at the same time gave a strong idea of the spanning of the shore-interval. This departure tended to further improvement in the design, as it afforded opportunity for gradually diminishing the width of the spans towards the ends of the bridge. Excellent specimens of this type were the Obermainbrücke at Frankfort-on-Main (built by Schmick after Lauter's ideas), the bridges at Offenbach, Hannöversch Münden, Mainz (over the Rhine, an extremely pleasing structure), &c. The same principle of variation in the width of the span was also well applicable where the abutments of the bridge were at different levels, such as at Basel, Switzerland. The Basel arched bridge was noted for the clever treatment of the difficulty of having an ascending platform. Here the width of span gradually increased from the lower end to the upper end.

Fig. 56.



Bridge Over the River Mosel at Trarbach.

Mr. Lineham. Mr. W. J. Lineham remarked that the importance of the subject of the Paper could scarcely be overrated, and if the Author's initiative would only be followed by other competent Papers dealing with bridges in their æsthetic sense, a great change might result in bridge design. It seemed unlikely that engineers would have to do with the masonry arched bridge in the future, so that any remarks upon it could only relate to the further beautifying of existing structures. Long horizontal lines should be broken by "refuges" supported on pillars more or less heavy. The lighter pillar in *Fig. 14* was well shaped, and would be strong enough for the purpose; but it appeared rather paltry in connection with the proportions of the bridge, and he would certainly prefer the ornamentation of Blackfriars Bridge, to which the Author had not referred. Mediæval architects had been very fond of excrescences on bridges, from refuges up to chapels, *e.g.*, the chantrey chapel on Wakefield Bridge. He fully agreed with the Author's condemnation of niches without statues, as in Fig. 2, Plate 2; niches had

Mr. Lineham.

been much used by the Romans, but the figures had never been absent. The Alexander III. Bridge was the latest and perhaps the most brilliant example of the small-span structure. The ornamentation was perfect and in thoroughly good taste, and it seemed doubtful whether the bridge could be improved in any particular. As regarded utility the bridge left very little head-room for the passing of boats, except near the centre, and even as a matter of beauty, a more elliptical form of arch would have served better. With the rise at his disposal, however, the engineer could scarcely have done otherwise. The one feeling that interfered with the perfect satisfaction of an educated observer was a fear that the rise was too small, and that a somewhat heavy load would assuredly cause collapse. This feeling became strengthened on walking across the bridge itself and observing the large amount of vibration. A bridge of recent construction between Passy and Auteuil had always appeared to Mr. Lineham to be admirable. The river was here very wide, and there were two piers in the water, but the spans were large and of low rise, as in the example previously mentioned. The curves were much finer, in his opinion, than the arc of the Alexander III. Bridge, and the extreme simplicity of the structure, unornamented except by colossal bronze sitting figures at the piers, was very charming. In dealing with large steel bridges many serious difficulties arose, which in most cases were insuperable; and the Author might have considerably aided the discussion of the subject had he treated these bridges by means of perspective views. It appeared to Mr. Lineham impossible to obtain a real idea of the effect of one of these large structures on the mind of the observer, except by means of photographs taken from the usual points of view. Even then the idea of grandeur due to size was not obtained, but it might be noticed how beautifully the lines of a stream were cut by the curves of the metal arches, as in the Berne Bridge; the high-level bridge at Newcastle might even be admired as seen from the quay, broken by the lines of the shipping. Suitability to surroundings was the most important point of all in the æsthetic treatment of bridges, and all premiated designs should be set in a model of the landscape, tastefully finished by good artists, so that views might be obtained from all likely points of vantage. He was aware that Mr. Eiffel had had landscapes painted on the flat behind his bridge-models, but he doubted if all the foregoing suggestions were ever carried out. Taken from their surroundings, he feared certain bridges, such as the Sukkur, the Poughkeepsie, the Borcea, and Saltash, could not

Mr. Lineham. be made beautiful by any treatment whatever; and some had no beauty even in their native landscape. The Forth Bridge appeared to him to have a distinct beauty of its own, and this was most probably due to the high economy of the structure. He had always thought that if a structure represented the utmost economy of material it must be essentially beautiful in line; for thus Nature would have built it, and then no one could have helped admiring it. The only difficulty in the way of the engineer-architect was that Nature was not in the habit of building bridges, and so he must needs deduce his lines from a consideration of what Nature would have done had she had a bridge to build. In this connection it was interesting to note *Fig. 43*, showing that the removal of a redundant member had the effect of improving the appearance. A bridge spanning a ravine might be so constructed as to appear to grow out of the landscape itself, and thus great harmony of line was obtained. Nothing illustrated his meaning so well as the simple but beautiful Garabit Viaduct (Fig. 35, Plate 3), where the supporting piers looked like two great pine trees, and the arch itself like branches of trees which had fallen forward till they met each other. Whether extra ornament might be applied to certain bridges would, he feared, always be a matter for debate. Yet, following Nature, whose forms were always perfect, there was a natural objection to abrupt endings, whether of base, capital, or springing. Cast-iron ornament was easily applied, but without great care it was apt to be patchy in appearance: and, on the other hand, it was often said that rolled bars and plates were unsuitable for decoration. For his own part, he thought an era of ornament in the latter material was opening up, of the future development of which engineers had but mere ideas; for, given a sufficient scale, the most charming growths could be imitated in section-bars. There was a staircase in the new "Grand Palais" at Paris which was so ornamented, and anyone who had seen it would admit the charm of these products of the section-rolls when directed by the eye of the artist. The Author deserved thanks for opening up this important subject.

1. Mr. Charles Macdonald, of New York, remarked that the Author struck the key-note of æsthetic construction in his reference to the works of Nature as the true guide. A study of natural law led to the inevitable conclusion that the lines of least resistance were followed in every change which occurred in existing conditions, whether it were the growth of a tree, the flow of a river, or the slow but certain modification of mountain forms. Not

Mr. Macdonald.

a single particle of matter changed its position except upon such lines, with the result that each new combination was effected with a minimum expenditure of energy, and with the most expressive, and therefore impressive, effects. To apply this rule to bridge construction, it was only necessary to determine the most scientifically economical combination of material to effect the desired result, and an outline would be found which, to the artistic eye, carried conviction that the beautiful had been combined with the good and the true. It was not enough to say that a bridge was a good bridge, in that it was strong enough to carry the required load. Any engineer who was familiar with the laws of statics could calculate the stresses and proportion the material for a given diagram in which the number of panels and relation of height to span was taken arbitrarily; and the result would be that the structure so proportioned would be as strong as might be desired for the required purpose. But, if the diagram so chosen did not present a pleasing appearance, it would be found that more material had been expended in meeting the requirements than would have been the case had a more scientific arrangement been adopted. A striking instance of this was to be observed in the change which had taken place in the design of simple fixed trusses, with a span of, say, 500 feet. The earlier practice had been parallel top and bottom chords with a proportion of span to height in the neighbourhood of 10 to 1; whereas now the accepted practice was to curve either one chord or the other, according to circumstance, thereby obtaining the same strength with less material. In this connection experience of the Hawkesbury Bridge might be referred to, as this was one of the structures mentioned in the Paper. The original design for this bridge had involved trusses with parallel chords and inclined end posts; before construction had actually commenced it had been found that by raising the top chord for the three centre panels (*Fig. 42*) a saving in material was effected; and before the bridge had been completed, further investigation had proved conclusively that an arched top chord, as in *Fig. 41*, would have resulted in a further saving, with a very evident improvement in appearance. It had been asserted that the cantilever type did not lend itself readily to artistic construction. Whilst it was true that most of the existing examples were open to this criticism, the cantilever must not be condemned for that reason alone. There were many situations in which a properly constructed cantilever would prove to be the most economical solution of the problem, and it therefore remained with the engineer to combine economy and

Mr. Macdonald. beauty in his design. The relative lengths of projecting brackets and suspended span must first be determined on economic lines; after which the determination of the proper proportions of each became a simple problem. To begin with the suspended span; if the length warranted, the upper chord should be curved as in the case of a through bridge, for reasons already referred to in the case of simple fixed spans, inasmuch as the conditions were exactly similar. With the projecting bracket, whilst the economic proportion of height to length was a matter easily determined by calculation, there was no necessity for transmitting stresses by straight lines to the top of the tower and thence back to the anchorage, when a graceful curve would effect the same purpose; neither should the intermediate loads between the tower and the outer end of the bracket be counterbalanced entirely through the anchorage, when a more economical balance could be effected through corresponding intermediates in the anchor span. It should be obvious that the engineer must not attempt to apply the cantilever principle where other forms of construction would be more appropriate. It would be a breach of privilege, so to speak, to spend thus a client's money merely for the purpose of gratifying personal ambition. At least one notable example of this misapplied energy was mentioned in the Paper. Probably it never would be referred to as an artistic success. Stiffened suspension bridges for long spans were rapidly coming into notice where the limit of economy of the cantilever was exceeded. The proper proportions of steel towers and the suspension curvature were comparatively simple of determination; but the arrangement of the necessary stiffening-trusses was more complicated. The bridges across the East River, New York, had stiffening-trusses with parallel chords, but for railway traffic it would be difficult and expensive to secure the necessary rigidity by following these lines.

r. Morton. Mr. D. H. MORTON observed that Papers of the class to which that under discussion belonged seldom came before the Institution; but it might be worthy of consideration whether Papers and discussions of an abstract and academical character might with advantage appear more frequently in the "Proceedings," which were chiefly occupied by records of work accomplished. The Author was to be congratulated upon his courage in bringing forward a subject which, as he had indicated, had been much neglected by engineers, and which, when discussed at all, generally proved to be highly controversial. The practical suitability of a bridge or other similar structure to fulfil the functions for which it had been

called into existence, were capable of proof, more or less definitive, by calculation, by test-loading, and by daily experience. When the æsthetic side of the subject was approached, the case was much altered. The discussion passed from the solid and utilitarian into the ethereal realm of taste, of the fine arts, in fact; and without some appreciation of fine art, and some systematised knowledge of the art of architecture, the engineer could hardly avoid producing structures which were frankly ugly. As the Author pointed out, this architectural knowledge was not to be used as a means of adding extraneous ornament in improper places, or of working up badly-copied architectural details on unsuitable materials. True decoration was never incongruous; enrichments on engineering works might readily be overdone, and in many cases they might very properly be dispensed with. Strength, dignity and simplicity were the characteristics of engineering works successfully treated; the leading essential or utilitarian features of the design were seized upon and accentuated, and a pleasing effect was produced by skilful and orderly arrangement, good grouping and proportions. All were acquainted with engineers who did not feel that they had any responsibility regarding the æsthetic side of their work; they were like men without the saving grace of humour, they did not know how much they missed in going through the world. But apart from such cases of arrested development, it was to be hoped that the majority of engineers aspired not only to meet the requirements of the Board of Trade, County Council, or Highways Committee, but to earn the approval of their brethren and of the community at large, by creating something which was capable of delighting the eye and the mind. Such aspirations could only be realised by men who had added the study of architecture to sound constructive experience, or who had been fortunate enough to secure the collaboration of an architect who was sufficiently broad-minded to enter heartily into the spirit of the general design, and to avoid the temptation to use the engineer's work merely as a scaffold on which to exhibit samples of his own affectations. Collaboration, however, was difficult. As the Author indicated, a few of the noblest engineering structures were a law unto themselves, because of their magnitude and because of the obvious difficulties which had had to be overcome in their construction; but such cases were few. Much of the engineer's work lay in urban districts, requiring treatment in harmony with architectural surroundings, or the blending of iron and steel ribs or girders with masonry piers or abutments. An engineer could not touch masonry above the surface of land or

Mr. Morton.

Mr. Morton. water without entering the domain of architecture, and if he would dabble in mouldings and classic orders, without having given some attention to the broad principles of the art, he would certainly produce results calculated to make accomplished architects gnash their teeth. The Author deserved the thanks of the Institution for having prepared a Paper which showed so clearly that, in order to secure successful design, a knowledge of the fine arts must be included amongst the qualifications of the engineer.

Mr. Statham. Mr. H. HEATHCOTE STATHAM having had the honour recently of reading a Paper [1] before the Royal Institute of British Architects on "The Æsthetic Treatment of Engineering Structures," was naturally much interested in the subject. With the opinions expressed in the Author's able and thoughtful Paper he was generally in entire agreement; there were only two points on which he would raise a question. In regard to the pedestals (or, rather, pylons) which flanked the entry to the Alexander III. Bridge at Paris being too high in proportion to the line of the arch, they should not be regarded as part of the bridge design. They were monumental erections intended to give dignity to the bridge approaches (just as the Romans, in the bridge at St. Chamas, had erected an arch at each end with the same object); and, in connection with the Exhibition buildings, they had also the object of carrying on the architectural vista of the avenue from the art-palaces down to the Invalides, so as not to leave a gap where the river crossed. Secondly, he did not agree with the suggestion that piers built in a running river should be of the same design on the up-stream and the down-stream face. Some degree of projection on the down-stream side might be desirable to lessen scour; but inasmuch as character in a structure arose from its fitness to the practical conditions, it seemed absurd to design a pier in a running river, where the water-pressure was all in one direction, in the same way as a pier in a tidal river, where the water-pressure was in both directions alternately. Symmetry of structure was out of place where the forces exerted on opposite sides of the structure were entirely different. To take an example on a large scale, he would point to the character given to the Victoria Bridge over the St. Lawrence by the immense cut-water buttresses on the up-stream side; to repeat those on the down-stream side, merely for "symmetry," would mean waste of material and loss of character. What was true on a large scale was true on a small scale. The modern engineer who imitated stone structure in iron

[1] Journal of Proceedings R. I. B. A., vol. vi., 3rd Series, p. 385.

had been defended on the ground that the Greeks had imitated wooden structure in stone; but no one who had studied Greek architecture, or the history of architectural development generally, could regard such an idea as otherwise than palpably absurd. The Doric column was an entirely masonic form; its *origines* were to be traced in the sixteen-sided stone columns of Beni-Hassan and Deir-el-Bahari; and the farther back the matter was traced, as far as examples of the Doric column existed, the thicker and more massive were the columns. The entablature of the Doric order (and of that alone) showed indeed clear traces of its wooden origin, but in a form entirely "mason-ified," so to speak; it was not an imitation of wooden structure, but only a reminiscence of it, translated into stone. All architecture, for the matter of that, went back ultimately to the hut or the wigwam, if the connecting links were forthcoming. In regard to the general question, engineering structures might be classed under two heads: pure structure, and decorated structure. Pure structure, unreservedly displayed, could never be in bad taste; such structure was its own justification. Therefore he had no sympathy with architects who called the Forth Bridge, for instance, ugly; it was not beautiful in one sense of the word, certainly, it was not a decorative design, but it was a grand and stupendous structure, and as such ought to be interesting and attractive to everyone with any feeling for or knowledge of structure. Similarly with London Bridge, a grand structure of granite with scarcely any attempt at ornament, which was perfectly satisfactory to the eye. No doubt architects and artists would rightly prefer stone to steel where it could be used; its surfaces were broader, it was more monumental both in fact and in appearance, and it was harmonised with nature by weathering, and did not require painting. But the plainest and most uncompromising steel structure was preferable to a stone or granite one bedizened with bad and ill-designed ornament. No doubt occasions would arise when it was suitable and desirable that a bridge should be treated in a decorative manner; but this was not to be achieved either by giving it an archæological treatment, or by plastering on to it architectural details which had no reference to the structure. The Tower Bridge afforded a sad example of both mistakes. It had been supposed that because it was near a mediæval building, therefore it must be mediæval to match. There could not be a more absurd idea. The Tower of London (so far as the original work remained) represented the manner in which the men of that day had naturally built a fortress; the best way then known. To

Mr. Statham.

Mr Statham. follow their example, the bridge should have been frankly designed and constructed in the best way now known. Instead of that, the real construction was masked by a gew-gaw architectural skin of modern-mediæval design, and suspension chains were made to appear to hang upon sham masonry towers which they would in fact rake down at once if the construction were what it appeared to the eye to be. The same mistake, in a less flagrant form, had been made in the case of Conway tubular bridge. On this head he might support his opinion by that of the late Mr. Gilbert Hamerton, a critic of not only English but European fame. Speaking of the Menai tubular bridge, Mr. Hamerton had said:—

"The whole bridge is admirable as a work of art, though the art is very simple and severe. The long line of tube (which looks like a great beam) is fortunately broken by the piers of marble which are finished above the beam as towers, and the majesty that naturally belongs to a work of colossal size and weight is enhanced by the prudent use of some architectural adornment. The tubular bridge over the River Conway near the castle is less fortunate, because the neighbourhood of a great mediæval building led the architect of the bridge to adopt a castellated style for the entrances to the tubes—a style which might be more or less in harmony with the fortress, but would scarcely in any other situation have been chosen to accompany a bridge which was nothing but two parallel beams."

Apart from what might be called the "archæological craze," it was essential that any decorative treatment of a bridge should be such as arose out of and assisted to express the construction. This was not to be done by taking architectural details (so-called) out of books and clapping them on as a kind of addition. It was this kind of process which had spoiled many recent engineering works. It was the common British fallacy about questions of art, that all such things were matters of opinion. Beyond a certain point, no doubt, artists would differ in opinion as to what they liked best. But up to the point where it was still a question of good or bad taste, of right or wrong, artists, as a matter of fact, differed very little in opinion, if it were a matter of opinion; but it was not. The difference between "good" and "bad" in design was a matter not of opinion but of perception; perception which was only acquired by study of the subject. One of the first things, for instance, which a young architectural student was made to do, was to study and draw the classic orders carefully; not necessarily with a view to imitating them, but because they represented the severest study in the proportion of details to a whole which architecture had to give; the column and entablature forming (to borrow a term from construction) the "element" of the design, in which every

detail was designed, and every moulding profiled, with reference to the whole. The mere study of the profiles of Greek mouldings, with their exquisitely refined curves, was in itself a kind of liberal education. If engineers went through any such training, they would perceive some things which they did not perceive now. They would not, for instance, imagine that they were giving "power" to a pier by capping it with a single moulding of 3 feet girth—a process which had only the double effect of rendering it coarse in appearance, and at the same time reducing the scale. They would not introduce clumsy and ill-profiled mouldings, or travesties of classic ornament magnified to a Brobdingnagian size. They would not disfigure a bridge-pier by such tawdry ornament as was to be seen on the piers of Blackfriars Bridge, a first-rate engineering work entirely ruined and vulgarised by its so-called ornament. It was not particularly good taste for architects to come to engineers and say, "You cannot do without us," and he did not wish to take that position. It might be pointed out, however, to engineers who might think themselves affronted (as some evidently did) by any proposal to associate an architect with them in the design of a bridge, that they had only to cross the Channel to find themselves in a country where that was considered a natural and necessary course with all important bridges built with public funds, and where the public authorities would be severely criticised if they did not take that course. In the case of the Alexander III. Bridge, the very lamp-standards had been put into the hands of one of the first of the younger sculptors of the day, who had shown a special talent in decorative modelling. In England they would have been designed in the engineer's office, or perhaps made from a foundry pattern. But what architects might say to engineers, without any imputation of bad taste, was this: "If you wish to treat your structures decoratively and to add to them that kind of expression which architectural detail can give, make the study of architectural design and detail a part of your professional education, so that you may learn how to handle it, and acquire a perception of its use and meaning." If engineers replied (as they perhaps would) that they had neither time nor inclination for such study, then architects would ask them (and surely it was a reasonable request), in that case, to at least be good enough to let it alone, and to give plain unadorned structure, which, at all events, must be interesting, and could not be in bad taste.

Mr. Statham.

Mr. J. STÜBBEN, of Cologne, agreed with the Author's view that a bridge must owe its æsthetic character to its appearance as a

Mr. Stübben.

Mr. Stübben. whole, that was, to the arrangement and outline of its essential constructional elements, and not to subsequently-applied meaningless ornamentation. The Bonn, Grünenthal, Garabit, Müngsten, Alexander III., and Niagara Falls and Clifton Bridges fulfilled this condition. The æsthetic impression which they gave was satisfactory. Moreover, suitable decorative treatment of the members was not excluded, as the Bonn and Alexander III. Bridges showed. Figs 27, 28, 29, and 30, Plate 2, also showed, in his opinion, designs calculated to produce a pleasing general impression. On the other hand, none of the bridges of the cantilever type shown in Figs 19–26 was of satisfactory æsthetic appearance.

Mr. Thorpe. Mr. W. H. THORPE thought the Author's criticism of abutment-piers in long masonry viaducts, as justifying their existence only in the event of failure, open to question, and that they served a purpose other than that of only limiting the amount of damage, if any occurred; for the greater number of spans being heavily loaded, the remainder might suffer by the aggregate effect of the loaded spans concentrated as an effort to close the remainder, accompanied by a considerable movement of the pier-tops nearest to which the extraneous load ended. The abutment-pier checked this tendency, and it was not unreasonable to think that an appreciation of some such effect in the mind of the observer rendered the adoption of such piers quite consonant also with æsthetic principles. As to the use of double cut-waters in bridge-piers, the plea for symmetry need not be the only reason for their existence. With a square face to the down-stream end of a pier, flow of water through the bridge-openings would be less free than with piers pointed at both ends, due no doubt to the eddying and reverse currents incidental to a square-ended obstruction. Perhaps the most successful productions of the engineer, considered from the point of view dealt with by the Author, were those larger works in which, the material being iron or steel, the outline and principal internal lines, whilst fully satisfying structural requirements, conveyed also to the mind of the ordinary observer a sense of fitness. In such structures, supplementary ornament was commonly and rightly absent. With smaller metal bridges it was customary to challenge admiration by the use of forms usually associated with stone-work. It might be argued that, as many details in architecture had admittedly arisen from a reproduction in stone of forms originally borrowed from Nature, or of earlier timber constructions, it should be equally allowable to produce these in, say, cast-iron;

but he submitted that though a stone structure in its simplest possible form, free from all artistic embellishment, and pleasing only in its proportions, might be legitimately improved by the tapering of columns, the enriching of bases and capitals, and the use of mouldings, since there was in this no violation of the original idea, yet in metallic bridges ornamentation could not with the same propriety be adopted if it took the form of facia-mouldings, elaborately pieced together, united by internal flanges and bolts, and applied to the main structure by similar expedients; or, in the case of an arched bridge, of ornamental spandrels to the outer ribs, having no relation to the spandrel structure of the inner ribs. Such detail, not being a rational development of the real structure, failed to satisfy a critical taste, and became an extreme application of the principle, otherwise to be heartily accepted, that "Beauty is its own excuse for being." Mr. Thorpe.

The AUTHOR, in reply to the Correspondence, observed that it was perhaps not quite correct to characterise the land arches of the Menai Bridge as wholly redundant. The tying down of the landward chains to the masonry would tend to stiffen the bridge materially by reducing the horizontal movement of the chains at the saddles; the land chains would also thereby derive a certain amount of lateral rigidity, whilst it was apparent to the observer that the land arches must have been a considerable aid in erection. These, however, were only secondary reasons for their existence, and probably no modern suspension bridge would be found to perpetuate them. After all, it was principally these land arches in combination with the landscape which gave to the bridge its distinctive and unusual character. It was a remarkable coincidence that both the Menai and Britannia bridges should possess prominent features which were in a great measure redundant, and yet that those very features were mainly instrumental in imparting to the bridges one of their greatest charms. A few remarks might be made with regard to the increasing employment of the Monier and allied systems of construction. Mr. Clarke had advocated some such method of construction as a satisfactory means of screening an internal skeleton of ironwork by an outer covering of concrete. The Author thought that from an æsthetic point of view the objection might be raised that such arches would generally appear to possess an abnormally small thickness as compared with the masonry structures they were made to resemble, whilst there was nothing to indicate the presence of the reinforcing material within. It might be wise The Author.

The Author. also, before adopting this construction on an extensive scale, to enquire carefully into the actual durability of comparatively small sections of iron and steel when embedded in concrete. With reference to the æsthetic aspect of American bridge-design, he was glad to find competent critics in Canada and the United States express the conviction that material improvement was at present taking place. Speaking generally, American designs in the past had fallen lamentably behind those of their European contemporaries, and it was distinctly satisfactory to read the forcible remarks made by some of the American engineers. He could scarcely agree with Mr. Goupil as to the pleasing appearance of *Fig. 55*. This bridge appeared from the illustration to possess several of the faults of the Philadelphian example so ably described by Mr. Crowell. In selecting examples with which to illustrate the Paper, it had, of course, been impossible to include more than a very limited number, and he had since regretted having omitted to cite the suspension bridge at Budapest as an example in which the design of the piers had been eminently successfully treated, comparing very favourably indeed with those of the Brooklyn and Clifton bridges. The ornamental festoons on the Alexander III. Bridge, as remarked by Mr. Clarke, might well have been omitted without compromising the design, in which case the purely structural portion would have strongly resembled the Pont Mirabeau—a pleasing example in which just the required amount of structural ornament appeared to have been applied, although the latter bridge was not nearly so favoured by environment as the former. He regretted much his not having seen Mr. Statham's Paper, and he would certainly take an early opportunity of reading it. With regard to the very pronounced buttresses on the up-stream faces of the piers of the Victoria Bridge over the St. Lawrence, he had always been under the impression they were intended principally to act as ice-breakers rather than as cut-waters only, and that this accounted for their unusual size. In conclusion, he desired to thank the correspondents for their valuable remarks on the subject, and also for having drawn attention to many foreign bridges which, although perhaps not so familiar to the majority of English engineers, yet possessed many of the most desirable attributes of æsthetic design.

19 March, 1901.
JAMES MANSERGH, President,
in the Chair.

The Discussion upon the Paper on "The Æsthetic Treatment of Bridge Structures" occupied the evening.

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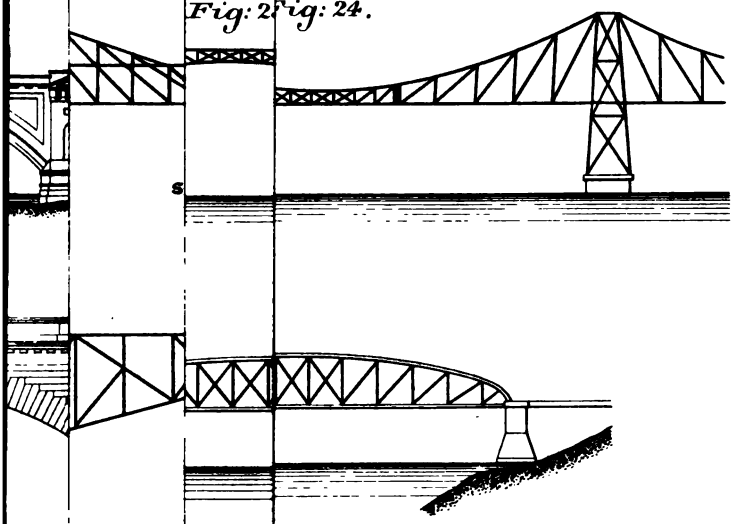
26 March, 1901.
JAMES MANSERGH, President,
in the Chair.

The Discussion upon the Paper on "The Æsthetic Treatment of Bridge Structures" was continued and concluded.

Fig: 23. *Fig: 24.*



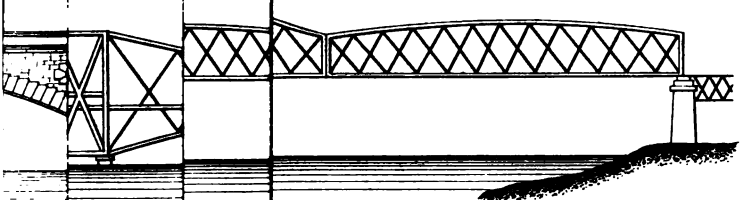
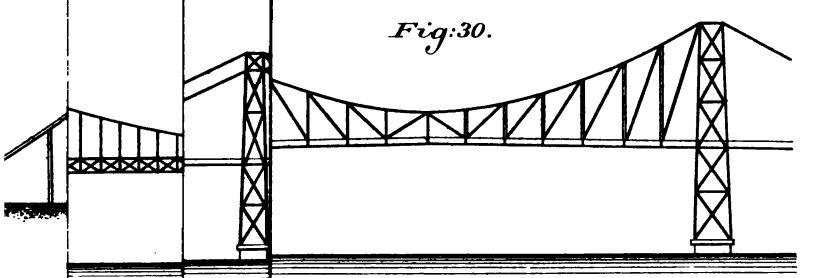


Fig: 30.



Proceeding

THOS KELL & SON LITH. 40 KING ST. COVENT GARDEN

Fig: 46.

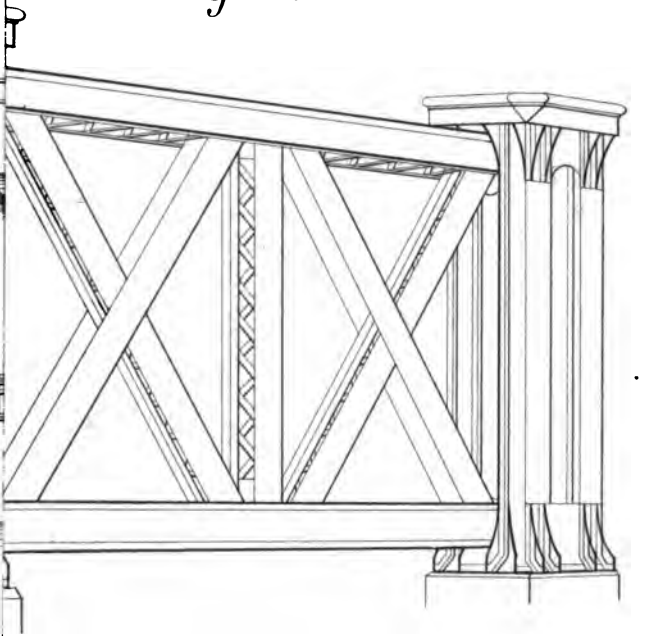
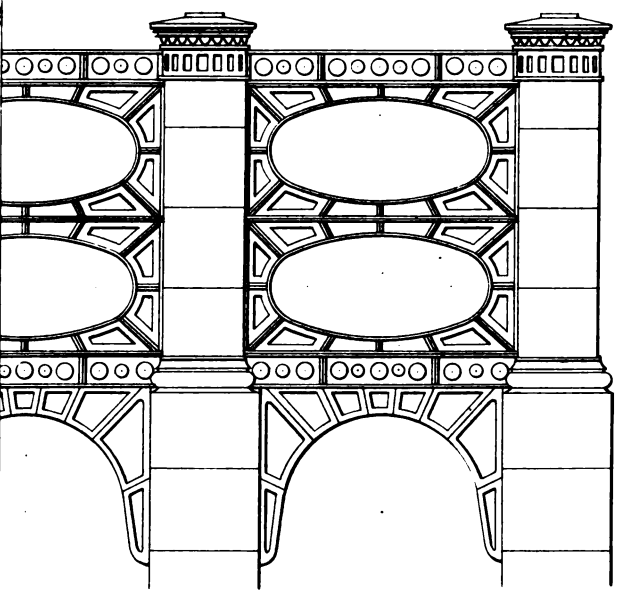
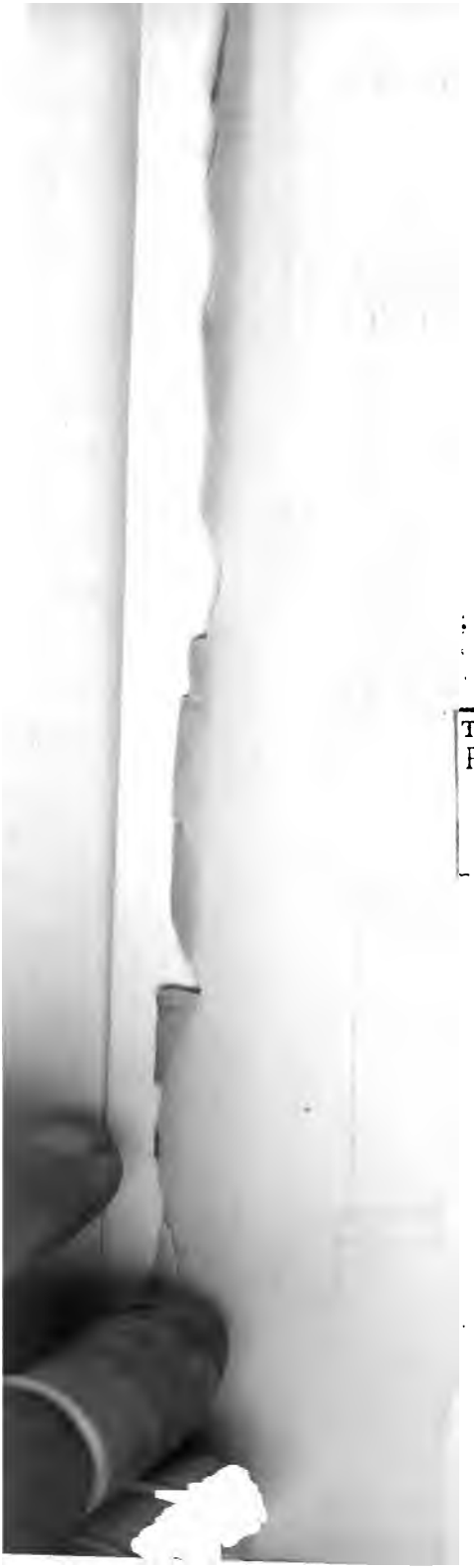


Fig: 47.



THOS KELL & SON, LITH. 40 KING ST COVENT GARDEN.



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